



Interlaken IP Core (2nd Generation) User Guide

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Last updated for Intel® Quartus® Prime Design Suite: Quartus Prime Pro 17.1 Stratix 10 ES Editions

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Contents

- 1 About this IP Core..... 3**
 - 1.1 Features..... 3
 - 1.2 Device Family Support..... 4
 - 1.3 Performance and Resource Utilization..... 5
 - 1.4 Release Information..... 6

- 2 Getting Started..... 7**
 - 2.1 Installing and Licensing IP Cores..... 7
 - 2.1.1 OpenCore Plus IP Evaluation..... 8
 - 2.2 Specifying the IP Core Parameters and Options..... 8
 - 2.3 IP Core Generation Output (Quartus Prime Pro Edition)..... 9
 - 2.4 Simulating the IP Core..... 12
 - 2.5 Compiling the Full Design and Programming the FPGA..... 12

- 3 Parameter Settings..... 13**

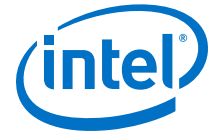
- 4 Functional Description..... 16**
 - 4.1 Interfaces..... 16
 - 4.2 IP Core Clocks..... 18
 - 4.3 Interleaved and Packet Modes..... 18
 - 4.4 High Level System Flow..... 19
 - 4.4.1 Interlaken TX Path..... 20
 - 4.4.2 Interlaken RX Path..... 26
 - 4.5 IP Core Reset..... 31
 - 4.6 M20K ECC Support..... 31
 - 4.7 Out-of-Band Flow Control..... 32

- 5 Interface Signals..... 36**
 - 5.1 Clock and Reset Interface Signals..... 37
 - 5.2 Transmit User Interface Signals..... 38
 - 5.3 Receive User Interface Signals..... 39
 - 5.4 Management Interface Signals..... 41
 - 5.5 Reconfiguration Interface Signals..... 42
 - 5.6 Interlaken Link and Miscellaneous Signals..... 42
 - 5.7 External PLL Interface Signals..... 45

- 6 Register Map..... 46**

- 7 Test Features..... 48**
 - 7.1 Internal Serial Loopback Mode..... 48
 - 7.2 External Loopback Mode..... 48

- A Document Revision History..... 49**

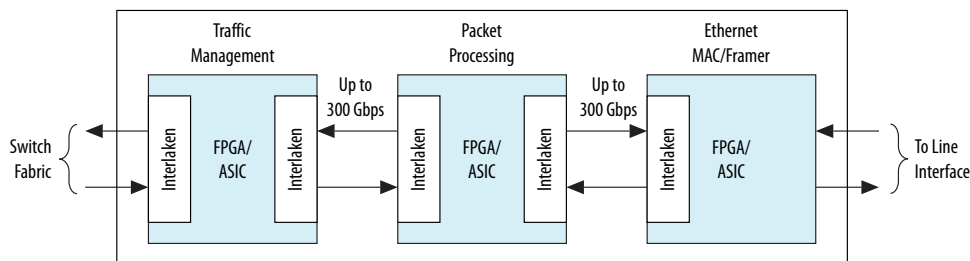


1 About this IP Core

Interlaken is a high-speed serial communication protocol for chip-to-chip packet transfers. The Interlaken IP core (2nd Generation) implements the *Interlaken Protocol Specification, Revision 1.2*. It supports multiple combinations of number of lanes (4 to 24) and lane rates from 6.25 gigabits per second (Gbps) to 25.3 Gbps, on Intel[®] Stratix[®] 10 devices, providing raw bandwidth of 25 Gbps to 300 Gbps.

Interlaken provides low I/O count compared to earlier protocols, supporting scalability in both number of lanes and lane speed. Other key features include flow control, low overhead framing, and extensive integrity checking. The Interlaken IP core incorporates a physical coding sublayer (PCS), a physical media attachment (PMA), and a media access control (MAC) block.

Figure 1. Typical Interlaken Application



Related Links

- [Interlaken IP Core \(2nd Generation\) Design Example User Guide](#)
Describes a simulating testbench and a hardware example design that supports compilation and hardware testing, to help you understand usage.
- [Interlaken Protocol Specifications](#)

1.1 Features

The Interlaken IP core (2nd Generation) has the following features:

- Compliant with the Interlaken Protocol Specification, Revision 1.2.
- Supports 4, 6, and 12 serial lanes in configurations that provide up to 300 Gbps raw bandwidth.
- Supports per-lane data rates of 6.25, 10.3125, 12.5 and 25.3 Gbps using Intel FPGA on-chip high-speed transceivers.
- Supports dynamically configurable BurstMax and BurstMin values.
- Supports Packet mode and Interleaved (Segmented) mode for user data transfer.
- Supports up to 256 logical channels in out-of-the-box configuration.

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- Supports optional user-controlled in-band flow control with 1, 2, 4, 8, or 16 16-bit calendar pages.
- Supports optional out-of-band flow control blocks.
- Supports memory block ECC.

Table 1. IP Core Supported Combinations of Number of Lanes and Data Rate

The following combinations are supported in Quartus Prime Pro 17.1 Stratix 10 ES Editions .

Number of Lanes	Lane Rate (Gbps)			
	6.25	10.3125	12.5	25.3
4	Yes ¹	-	-	-
6	-	-	-	Yes ²
12	-	Yes ¹	Yes ¹	Yes ²

Table 2. IP Core Theoretical Raw Aggregate Bandwidth

The following combinations are supported in Quartus Prime Pro 17.1 Stratix 10 ES Editions .

Number of Lanes	Lane Rate (Gbps)				Number of Words	Data Width (bits)
	6.25	10.3125	12.5	25.3		
4	25 ¹	-	-	-	4	256
6	-	-	-	150 ²	8	512
12	-	123.75 ¹	150 ¹	-	8	512
12	-	-	-	300 ²	16	1024

Related Links

[Interlaken Protocol Specifications](#)

1.2 Device Family Support

The following lists the device support level definitions for Intel FPGA IP cores:

-
- 1 Supported in Stratix 10 devices with L-tile transceivers.
 - 2 Supported in Stratix 10 devices with H-tile transceivers.



- **Advance support** — The IP core is available for simulation and compilation for this device family. Timing models include initial engineering estimates of delays based on early post-layout information. The timing models are subject to change as silicon testing improves the correlation between the actual silicon and the timing models. You can use this IP core for system architecture and resource utilization studies, simulation, pinout, system latency assessments, basic timing assessments (pipeline budgeting), and I/O transfer strategy (data-path width, burst depth, I/O standards tradeoffs).
- **Preliminary support** — The IP core is verified with preliminary timing models for this device family. The IP core meets all functional requirements, but might still be undergoing timing analysis for the device family. It can be used in production designs with caution.
- **Final support** — The IP core is verified with final timing models for this device family. The IP core meets all functional and timing requirements for the device family and can be used in production designs.

Table 3. Device Family Support

Device Family	Support
Stratix 10	Advance

1.3 Performance and Resource Utilization

Lists the resources and expected performance for selected variations of the Interlaken IP core using the Quartus Prime Pro 17.1 Stratix 10 ES Editions.

Table 4. FPGA Resource Utilization

Device	Parameters		Resource Utilization			
	Number of Lanes	Data/Lane Rate (Gbps)	ALMs needed	Logic Registers		M20K Blocks
				Primary	Secondary	
Stratix 10	4	6.25	9500	15800	4500	20
	12	10.3125	20100	38000	9000	44
	12	12.5	20300	38100	8800	44

Note: For 6x25.3Gbps and 12x25.3Gbps combinations, the resource utilization and FPGA programming file (.pof) support is not available in Quartus Prime Pro 17.1 Stratix 10 ES Editions.



1.4 Release Information

Table 5. IP Core Release Information

Item	Value	
Version	Quartus Prime Pro 17.1 Stratix 10 ES Editions	
Release Date	May 2017	
Ordering Code	Aggregate Bandwidth	Ordering Code
	20G to <100G	IP-ILKN/50G
	100G to <200G	IP-ILKN/100G
	200G to <400G	IP-ILKN/200G



2 Getting Started

The following sections explain how to install, parameterize, simulate, and initialize the Interlaken IP core.

Related Links

- [Introduction to Intel FPGA IP Cores](#)
Provides general information about all Intel FPGA IP cores, including parameterizing, generating, upgrading, and simulating IP cores.
- [Creating Version-Independent IP and Qsys Simulation Scripts](#)
Create simulation scripts that do not require manual updates for software or IP version upgrades.
- [Project Management Best Practices](#)
Guidelines for efficient management and portability of your project and IP files.

2.1 Installing and Licensing IP Cores

The Intel Quartus® Prime software installation includes the Intel FPGA IP library. This library provides useful IP core functions for your production use without the need for an additional license. Some IP cores in the library require that you purchase a separate license for production use. The OpenCore® feature allows evaluation of any Intel FPGA IP core in simulation and compilation in the Quartus Prime software. Upon satisfaction with functionality and performance, visit the Self Service Licensing Center to obtain a license number for any Intel FPGA product.

The Quartus Prime software installs IP cores in the following locations by default:

Figure 2. IP Core Installation Path

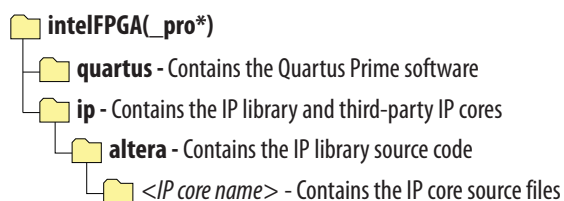


Table 6. IP Core Installation Locations

Location	Software	Platform
<drive>:\intelFPGA_pro\quartus\ip\altera	Quartus Prime Pro Edition	Windows*
<drive>:\intelFPGA\quartus\ip\altera	Quartus Prime Standard Edition	Windows
<home directory>:/intelFPGA_pro/quartus/ip/altera	Quartus Prime Pro Edition	Linux*
<home directory>:/intelFPGA/quartus/ip/altera	Quartus Prime Standard Edition	Linux

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2.1.1 OpenCore Plus IP Evaluation

The free OpenCore Plus feature allows you to evaluate licensed MegaCore IP cores in simulation and hardware before purchase. Purchase a license for MegaCore IP cores if you decide to take your design to production. OpenCore Plus supports the following evaluations:

- Simulate the behavior of a licensed IP core in your system.
- Verify the functionality, size, and speed of the IP core quickly and easily.
- Generate time-limited device programming files for designs that include IP cores.
- Program a device with your IP core and verify your design in hardware.

OpenCore Plus evaluation supports the following two operation modes:

- Untethered—run the design containing the licensed IP for a limited time.
- Tethered—run the design containing the licensed IP for a longer time or indefinitely. This operation requires a connection between your board and the host computer.

Note: All IP cores that use OpenCore Plus time out simultaneously when any IP core in the design times out.

Related Links

- [Quartus Prime Licensing Site](#)
- [Quartus Prime Installation and Licensing](#)

2.2 Specifying the IP Core Parameters and Options

The IP parameter editor allows you to quickly configure your custom IP variation. You specify IP core options and parameters in the Quartus Prime Pro Edition software.

The Interlaken IP core is not supported in Qsys. You must use the IP Catalog accessible from the Quartus Prime Pro Edition **Tools** menu. The Interlaken IP core does not support VHDL simulation models. You must specify the Verilog HDL for both synthesis and simulation models.

1. Create or open a Quartus Prime project (.qpf) which has a targeted device family as Stratix 10.
2. In the IP Catalog (**Tools > IP Catalog**), locate and double-click the **Interlaken IP Core (2nd Generation)** to customize. The parameter editor appears.
3. Specify a top-level name for your custom IP variation. The parameter editor saves the IP variation settings in a file named `<your_ip>.ip`. Click **OK**.
4. Specify the parameters and options for your IP variation in the parameter editor, including one or more of the following. Refer to [Parameter Settings](#) on page 13 for information about specific IP core parameters.
 - Specify parameters defining the IP core functionality, port configurations, and device-specific features.
 - Specify options for processing the IP core files in other EDA tools.
5. For Stratix 10 variations, follow these steps:
 - a. Click **Generate HDL**. The **Generation** dialog box appears.



- b. Specify output file generation options, and then click **Generate**. The IP variation files generate according to your specifications.
Note: To generate the demonstration testbench and example design, you must specify Verilog HDL for both synthesis and simulation models.
 - c. Optionally, click the **Generate Example Design** button in the parameter editor to generate a demonstration testbench and example design for your IP core variation.
 - d. Click **Finish**. Click **Yes** if you are prompted to add files representing the IP variation to your project.
6. After generating and instantiating your IP variation, make appropriate pin assignments to connect ports.

Related Links

[Interlaken IP Core \(2nd Generation\) Design Example User Guide](#)

Describes a simulating testbench and a hardware example design that supports compilation and hardware testing, to help you understand usage.

2.3 IP Core Generation Output (Quartus Prime Pro Edition)

The Quartus Prime software generates the following output file structure for individual IP cores that are not part of a Qsys Pro system.

Figure 3. Individual IP Core Generation Output (Quartus Prime Pro Edition)

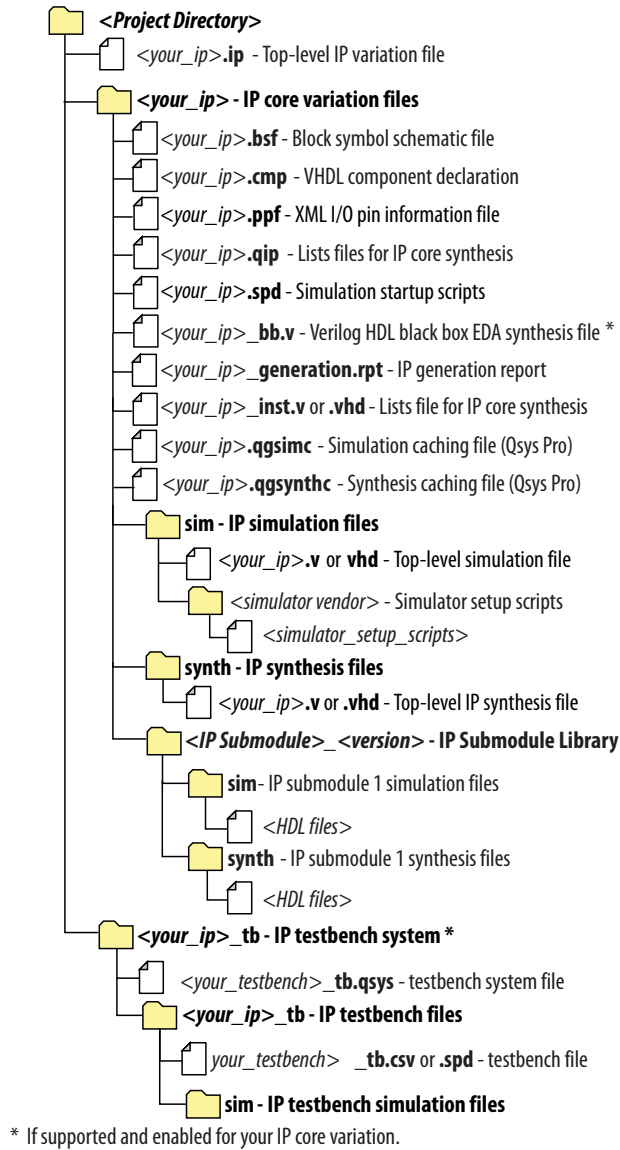


Table 7. Files Generated for IP Cores

File Name	Description
<your_ip>.ip	Top-level IP variation file that contains the parameterization of an IP core in your project. If the IP variation is part of a Qsys Pro system, the parameter editor also generates a .qsys file.
<your_ip>.cmp	The VHDL Component Declaration (.cmp) file is a text file that contains local generic and port definitions that you use in VHDL design files.
<your_ip>_generation.rpt	IP or Qsys Pro generation log file. Displays a summary of the messages during IP generation.

continued...



File Name	Description
<your_ip>.qgsimc (Qsys Pro systems only)	Simulation caching file that compares the .qsys and .ip files with the current parameterization of the Qsys Pro system and IP core. This comparison determines if Qsys Pro can skip regeneration of the HDL.
<your_ip>.qgsynth (Qsys Pro systems only)	Synthesis caching file that compares the .qsys and .ip files with the current parameterization of the Qsys Pro system and IP core. This comparison determines if Qsys Pro can skip regeneration of the HDL.
<your_ip>.qip	Contains all information to integrate and compile the IP component.
<your_ip>.csv	Contains information about the upgrade status of the IP component.
<your_ip>.bsf	A symbol representation of the IP variation for use in Block Diagram Files (.bdf).
<your_ip>.spd	Required input file for ip-make-simscript to generate simulation scripts for supported simulators. The .spd file contains a list of files you generate for simulation, along with information about memories that you initialize.
<your_ip>.ppf	The Pin Planner File (.ppf) stores the port and node assignments for IP components you create for use with the Pin Planner.
<your_ip>_bb.v	Use the Verilog blackbox (_bb.v) file as an empty module declaration for use as a blackbox.
<your_ip>_inst.v or _inst.vhd	HDL example instantiation template. Copy and paste the contents of this file into your HDL file to instantiate the IP variation.
<your_ip>.regmap	If the IP contains register information, the Quartus Prime software generates the .regmap file. The .regmap file describes the register map information of master and slave interfaces. This file complements the .sopcinfo file by providing more detailed register information about the system. This file enables register display views and user customizable statistics in System Console.
<your_ip>.svd	Allows HPS System Debug tools to view the register maps of peripherals that connect to HPS within a Qsys Pro system. During synthesis, the Quartus Prime software stores the .svd files for slave interface visible to the System Console masters in the .sof file in the debug session. System Console reads this section, which Qsys Pro queries for register map information. For system slaves, Qsys Pro accesses the registers by name.
<your_ip>.v <your_ip>.vhd	HDL files that instantiate each submodule or child IP core for synthesis or simulation.
mentor/	Contains a script msim_setup.tcl to set up and run a simulation.
aldec/	Contains a Riviera*-PRO script rivierapro_setup.tcl to setup and run a simulation.
/synopsys/vcs /synopsys/vcsmx	Contains a shell script vcs_setup.sh to set up and run a VCS* simulation. Contains a shell script vcsmx_setup.sh and synopsys_sim.setup file to set up and run a VCS MX* simulation.
/cadence	Contains a shell script ncsim_setup.sh and other setup files to set up and run an NCSIM simulation.
/submodules	Contains HDL files for the IP core submodule.
<IP submodule>/	For each generated IP submodule directory, Qsys Pro generates /synth and /sim sub-directories.



2.4 Simulating the IP Core

You can simulate your Interlaken IP core variation using any of the vendor-specific IEEE encrypted functional simulation models which are generated in the new `<instance name>_sim` or `<instance name>/sim` subdirectory of your project directory.

The Interlaken IP core supports the Synopsys VCS*, and Mentor Graphics Modelsim-SE* simulators. The Interlaken IP core generates only a Verilog HDL simulation model and testbench. The IP core parameter editor appears to offer you the option of generating a VHDL simulation model, but this IP core does not support a VHDL simulation model or testbench.

For more information about functional simulation models for Intel FPGA IP cores, refer to the *Simulating Intel FPGA Designs* chapter in volume 3 of the *Quartus Prime Pro Edition Handbook*.

Related Links

[Simulating Intel FPGA Designs](#)

2.5 Compiling the Full Design and Programming the FPGA

You can use the **Start Compilation** command on the **Processing** menu in the Quartus Prime software to compile your design. After successfully compiling your design, program the targeted Intel device with the Programmer and verify the design in hardware.

Related Links

- [Programming Altera Devices](#)
- [Design Compilation](#)



3 Parameter Settings

You customize the Interlaken IP core by specifying parameters in the IP parameter editor.

Table 8. Interlaken IP Core Parameter Settings

Parameter	Supported Values	Default Setting	Description
Meta Frame Length (words)	64-8192 words	2048	The Meta Frame Length parameter specifies the length of the meta frame, in 64-bit (8-byte) words. Smaller values for this parameter shorten the time to achieve lock. Larger values reduce overhead while transferring data, after lock is achieved.
Number of Lanes	4, 6, 12	12	The Number of Lanes parameter specifies the number of lanes available for Interlaken communication. The Interlaken IP core supports various combinations of number of lanes and lane rates. Ensure that your parameter settings specify a supported combination. Refer to <i>Table: IP Core Supported Combinations of Number of Lanes and Data Rate</i> Unfortunately, the editor allows you to select 8 and 24 lane options even though they aren't supported.
Data Rate	6.25, 10.3125, 12.5, and 25.3 Gbps	10.3125 Gbps	The Data Rate parameter specifies the data rate on each lane. All lanes have the same data rate (lane rate). The Interlaken IP core supports various combinations of number of lanes and lane rates. Ensure that your parameter settings specify a supported combination. Refer to <i>Table: IP Core Supported Combinations of Number of Lanes and Data Rate</i>
Enable M20K ECC Support	On/Off	Off	The Enable M20K ECC Support parameter specifies whether your Interlaken IP core variation supports the ECC feature in the M20K memory blocks that are configured as part of the IP core. You can turn this parameter on to enable single-error correct, double-adjacent-error correct, and triple-adjacent-error detect ECC functionality in the M20K memory blocks configured in your IP core. This feature enhances data reliability but increases latency and resource utilization.

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Parameter	Supported Values	Default Setting	Description								
Enable Native XCVR PHY ADME	On/Off	Off	<p>The Enable Native XCVR PHY ADME parameter specifies whether your Interlaken IP core variation supports the ADME feature.</p> <p>This parameter exposes debugging features of the Stratix 10 Native PHY IP core that specifies the transceiver settings in the Interlaken IP core.</p>								
Transceiver Reference Clock Frequency	Multiple	412.5 MHz	<p>The Transceiver Reference Clock Frequency parameter specifies the expected frequency of the <code>p11_ref_clk</code> input clock.</p> <table border="1"> <thead> <tr> <th>Data Rate per Lane (Gbps)</th> <th>Valid Frequencies (MHz)</th> </tr> </thead> <tbody> <tr> <td>10.3125</td> <td>206.25, 257.8125, 322.265625, 412.5, 515.625, 644.53125</td> </tr> <tr> <td>12.5, 6.25</td> <td>156.25, 195.3125, 250, 312.5, 390.625, 500, 625</td> </tr> <tr> <td>25.3</td> <td>126.4, 158.0, 197.5, 252.8, 320.0, 395.0, 412.5, 505.6</td> </tr> </tbody> </table>	Data Rate per Lane (Gbps)	Valid Frequencies (MHz)	10.3125	206.25, 257.8125, 322.265625, 412.5, 515.625, 644.53125	12.5, 6.25	156.25, 195.3125, 250, 312.5, 390.625, 500, 625	25.3	126.4, 158.0, 197.5, 252.8, 320.0, 395.0, 412.5, 505.6
			Data Rate per Lane (Gbps)	Valid Frequencies (MHz)							
			10.3125	206.25, 257.8125, 322.265625, 412.5, 515.625, 644.53125							
			12.5, 6.25	156.25, 195.3125, 250, 312.5, 390.625, 500, 625							
			25.3	126.4, 158.0, 197.5, 252.8, 320.0, 395.0, 412.5, 505.6							
<p>If the actual frequency of the <code>p11_ref_clk</code> input clock does not match the value you specify for this parameter, the design fails in both simulation and hardware.</p>											
<p>The Include In-Band Flow Control Functionality parameter specifies whether your Interlaken IP core includes an in-band flow control block.</p>											
<p>When Include In-Band Flow Control Functionality is turned on, the Number of calendar pages parameter specifies the number of 16-bit pages of in-band flow control data that your Interlaken IP core supports.</p> <p>Each 16-bit calendar page includes 16 in-band flow control bits. The application determines the interpretation of the in-band flow control bits. The IP core supports a maximum of 256 channels with in-band flow control.</p> <p>If your design requires a different number of pages, select the lowest supported number of pages which is larger than the number required, and ignore any unused pages. For example, if your configuration requires three in-band flow control calendar pages, you can set Number of calendar pages to 4 and use pages 3, 2, and 1 while ignoring page 0.</p>											
Number of Calender Pages	1, 2, 4, 8, and 16	1									

continued...



Parameter	Supported Values	Default Setting	Description
TX Scrambler Seed	-	0x0000deadbeef123	The TX Scrambler Seed parameter specifies the initial scrambler state. If a single Interlaken IP Core is configured on your device, you can use the default value of this parameter. If multiple Interlaken IP Cores are configured on your device, you must use a different initial scrambler state for each IP core to reduce crosstalk. Try to select random values for each Interlaken IP core, such that they have an approximately even mix of ones and zeros and differ from the other scramblers in multiple spread out bit positions.
VCCR_GXB and VCCT_GXB supply voltage for the transceivers	1.0V, 1.1V	1.0V	This parameter specifies the VCCR_GXB and VCCT_GXB transceiver supply voltage.
Transfer Mode Selection	Interleaved and Packet	Interleaved	The Transfer Mode Selection parameter specifies whether the Interlaken transmitter expects incoming traffic to the TX user data transfer interface to be interleaved or packet based.

A check-mark in the check box to the left of the parameter specifies that the IP core supports this feature. A check box with no check-mark indicates that the option is turned off, and the IP core does not support this feature.

Related Links

- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.



4 Functional Description

The Interlaken IP core provides the functionality described in the *Interlaken Protocol Specification, Revision 1.2*.

4.1 Interfaces

The Interlaken IP core supports the following interfaces:



- **User Data Transfer Interface**

The user data transfer interface, also known as application interface, provides up to 256 channels of communication to and from the Interlaken link. This interface is alike Avalon-ST interface which supports data bursts or packets, which are carried in the Interlaken MetaFrame Payload.

- **Interlaken Interface**

The Interlaken interface complies with the *Interlaken Protocol Specification, Revision 1.2*. It provides a high-speed transceiver interface to an Interlaken link.

- **Out-of-Band Flow Control Interface**

The optional out-of-band flow control interface conforms to the out-of-band requirements in *Section 5.3.4.2, Out-of-Band Flow Control, of the Interlaken Protocol Specification, Revision 1.2*.

- **Management Interface**

The management interface provides access to the Interlaken IP core internal status and control registers. This interface does not provide access to the hard PCS registers on the device. This interface complies with the Avalon Memory-Mapped (Avalon-MM) specification defined in the *Avalon Interface Specifications*.

- **Transceiver Control Interfaces**

The Interlaken IP core provides several interfaces to control the transceiver. The transceiver control interfaces in your Interlaken IP core variation depend on the device family the variation targets. The Interlaken IP core supports the following transceiver control interfaces:

- **External PLL Interface**

The Interlaken IP core variations that target Stratix 10 device require an external transceiver PLL to function correctly in hardware.

- **Transceiver Reconfiguration Interface**

The Stratix 10 transceiver reconfiguration interface provides access to the registers in the embedded Stratix 10 Native PHY IP core. This interface provides direct access to the hard PCS registers on the device. This interface complies with the Avalon Memory-Mapped (Avalon-MM) specification defined in the *Avalon Interface Specifications*.

Related Links

- [Interlaken Protocol Specifications](#)
- [Avalon Interface Specifications](#)
- [Interface Signals](#) on page 36
The IP core communicates with the surrounding design through multiple external signals.
- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

4.2 IP Core Clocks

Table 9. Interlaken IP Core Clocks

Clock Name	Description
pll_ref_clk	Reference clock for the RX CDR PLL in IP core variations that target an Stratix 10 device.
tx_serial_clk[NUM_LANES-1:0]	Clocks for the individual transceiver channels in Interlaken IP core variations that target an Stratix 10 device.
rx_usr_clk	Clock for the receive application interface.
tx_usr_clk	Clock for the transmit application interface.
mm_clk	Management clock for Interlaken IP core register access.
reconfig_clk	Management clock for Stratix 10 hard PCS register access, including access for Stratix 10 transceiver reconfiguration and testing features.

Related Links

- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
 For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
 For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

4.3 Interleaved and Packet Modes

You can configure the Interlaken IP core to accept interleaved data transfers from the application on the TX user data transfer interface, or to not accept interleaved data transfers on this interface. If the IP core can accept interleaved data transfers, it is in Interleaved mode, sometimes also called Segmented mode. If the IP core does not accept interleaved data transfers, it is in Packet mode. The value you specify for the **Transfer mode selection** parameter in the IP core parameter editor determines the IP core transmit mode.

In Packet mode, the Interlaken IP core performs *Optional Scheduling Enhancement based on Section 5.3.2.1.1 of the Interlaken Protocol Specification, Revision 1.2*. The IP core ignores the `itx_sob` and `itx_eob` signals. Instead, the IP core performs optional enhanced scheduling based on the settings of `BurstMax`, `BurstMin`, and `BurstShort`.

In Interleaved mode, the Interlaken IP core inserts burst control words on the Interlaken link based on the `itx_sob` and `itx_eob` inputs. The internal optional enhanced scheduling is disabled and the `BurstMax` and `BurstMin` values are ignored. `BurstShort` is still in effect. To avoid overflowing the transmit FIFO, you should not send a burst that is longer than 1024 bytes.

In Interleaved mode or in Packet mode, the Interlaken IP core is capable of accepting non-interleaved data on the TX user data transfer interface (`itx_din_words`). However, if the IP core is in Interleaved mode, the application must drive the `itx_sob` and `itx_eob` inputs correctly.



In Interleaved mode or in Packet mode, the Interlaken IP core can generate interleaved data transfers on the RX user data transfer interface (*irx_dout_words*). The application must be able to accept interleaved data transfers if the Interlaken link partner transmits them on the Interlaken link. In this case, the Interlaken link partner must send traffic in Interleaved mode that conforms with the Interlaken IP core *BurstShort* value.

Note: Intel recommends that the transmitter (link partner) only send packets with a minimum packet size of 64 bytes.

4.4 High Level System Flow

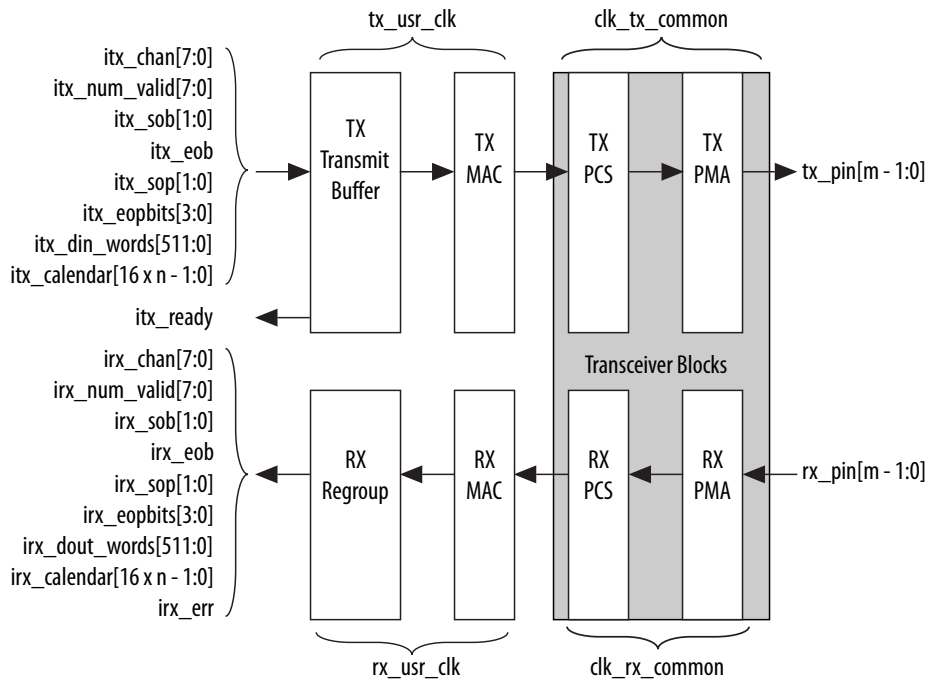
The Interlaken IP core consists of two paths:

- Interlaken TX path
- Interlaken RX path

Each path includes MAC, PCS, and PMA blocks. The PCS blocks are implemented in hard IP.

Figure 4. Interlaken IP Core Block Diagram

The figure illustrates the 8-word data transfer scenario.



Related Links

- [Avalon Interface Specifications](#)
- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)

For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

4.4.1 Interlaken TX Path

The Interlaken IP core accepts application data from up to 256 channels and combines it into a single data stream in which data is labeled with its source channel. The Interlaken TX MAC and PCS blocks format the data into protocol-compliant bursts and insert Idle words where required.

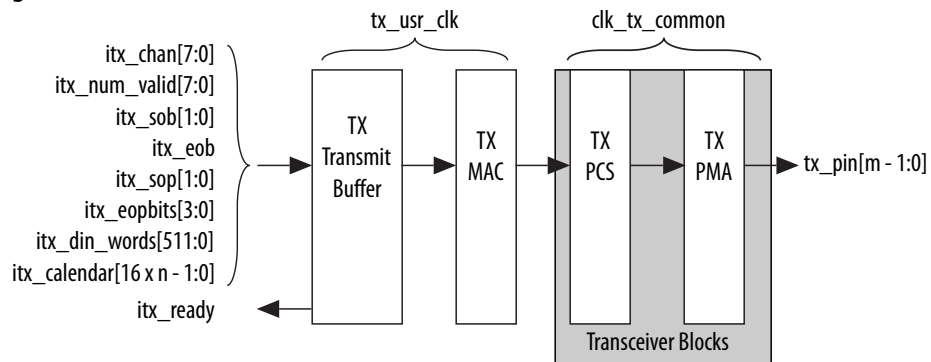
4.4.1.1 Transmit Path Blocks

The Interlaken IP core transmit data path has the following four main functional blocks:

- TX Transmit Buffer
- TX MAC
- TX PCS
- TX PMA

Figure 5. Interlaken IP Core Transmit Path Blocks

The figure illustrates the 8-word data transfer scenario.



TX Transmit Buffer

The Interlaken IP core TX transmit buffer aligns the incoming user application data, `itx_data`, in the IP core internal format.

TX MAC

The Interlaken IP core TX MAC performs the following functions:



- Inserts burst and idle control words in the incoming data stream. Burst delineation allows packet segmentation in the Interlaken protocol.
- Performs flow adaption of the data stream, repacking the data to ensure the maximum number of words is available on each valid clock cycle.
- Calculates and inserts CRC24 bits in all burst and idle words.
- Inserts calendar data in all burst and idle words, if you configure in-band flow control.
- Stripes the data across the PCS lanes. Configurable order, default is MSB of the data goes to lane 0.
- Buffers data between the application and the TX PCS block in the TX FIFO buffer. The TX PCS block uses the FIFO buffer to recover bandwidth when the number of words delivered to the transmitter is less than the full width.

TX PCS

TX PCS logic is an embedded hard macro and does not consume FPGA soft logic elements. The Interlaken IP core TX PCS block performs the following functions for each lane:

- Inserts the meta frame words in the incoming data stream.
- Calculates and inserts the CRC32 bits in the meta frame diagnostic words.
- Scrambles the data according to the scrambler seed and the protocol-specified polynomial.
- Performs 64B/67B encoding.

TX PMA

The Interlaken IP core TX PMA serializes the data and sends it out on the Interlaken link.

4.4.1.2 In-Band Calendar Bits on Transmit Side

When you turn on **Include in-band flow control functionality**,

- The `itx_calendar` input signal supports in-band flow control. It is synchronous with `tx_usr_clk`, but does not align with the packets on the user data interface. The Interlaken IP core reads the `itx_calendar` bits and encodes them in control words (Burst control words and Idle control words) opportunistically.
- The Interlaken IP core transmits each page of the `itx_calendar` bits on the Interlaken link in a separate control word, starting with the most significant page and working through the pages, in order, to the least significant page.
- The Interlaken IP core fills each flow control bit in each control word with the value of 1.

If you hold all the calendar bits at one, you indicate an XON setting for each channel. You should set the calendar bits to 1 to indicate that the Interlaken link partner does not need to throttle the data it transfers to the Interlaken IP core. Set this value by default if you choose not to use the in-band flow control feature of the Interlaken IP core. If you decide to turn off any channel, you must drive the corresponding bits of `itx_calendar` with zero (the XOFF setting) for that channel.



Consider an example where the number of calendar pages is four and `itx_calendar` bits are set to the value `64'h1111_2222_3333_4444`. In this example, the **Number of calendar pages** parameter is set to four, and therefore the width of the `itx_calendar` signal is $4 \times 16 = 64$ bits. Each of these bits is a calendar bit. The transmission begins with the page with the value of `16'h1111` and works through the pages in order until the least significant page with the value of `16'h4444`.

In this example, four control words are required to send the full set of 64 calendar bits from the `itx_calendar` signal. The Interlaken IP core automatically sets the Reset Calendar bit[56] of the next available control word to the value of one, to indicate the start of transmission of a new set of calendar pages, and copies the most significant page (`16'h1111` in this example) to the In-Band Flow Control bits[55:40] of the control word. It maps the most significant bit of the page to the control word bit[55] and the least significant bit of the page to the control word bit[40].

Table 10. Value of Reset Calendar Bit and In-band Flow Control Bits in the Example

The table shows the value of the Reset Calendar bit and the In-Band Flow Control bits in the four Interlaken link control words that transmit the `64'h1111_2222_3333_4444` value of `itx_calendar`.

Control Word	Reset Calendar Bit (bit [56])	In-Band Flow Control Bits (bits [55:40])
First	1	16'b0001000100010001 (16'h1111)
Second	0	16'b0010001000100010 (16'h2222)
Third	0	16'b0011001100110011 (16'h3333)
Fourth	0	16'b0100010001000100 (16'h4444)

For details of the control word format, refer to the *Interlaken Protocol Specification*, Revision 1.2.

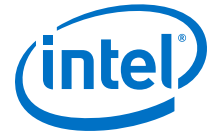
The IP core supports `itx_calendar` widths of **1, 2, 4, 8, and 16** 16-bit calendar pages. You configure the width in the IP core parameter editor.

By convention, in a standard case, each calendar bit corresponds to a single data channel. However, the IP core assumes no default usage. You must map the calendar bits to channels or link status according to your specific application needs. For example, if your design has 64 physical channels, but only 16 priority groups, you can use a single calendar page and map each calendar bit to four physical channels. As another example, for a different application, you can use additional calendar bits to pass quality-of-service related information to the Interlaken link partner.

If your application flow-controls a channel, you are responsible for dropping the relevant packet. Intel supports the transfer of the `itx_calendar` values you provide without examining the data that is affected by in-band flow control of the Interlaken link.

4.4.1.3 Transmit User Data Interface Examples

The following examples illustrate how to use the Interlaken IP core TX user data interface:

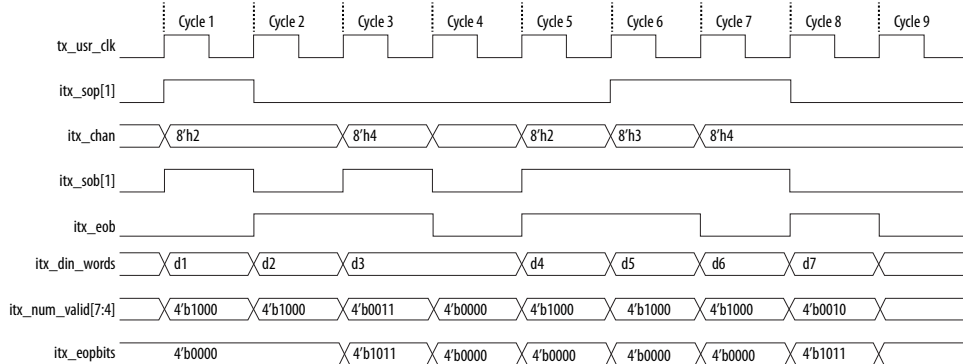


Interleaved Mode (Segmented Mode) Example

In Interleaved Mode, you are responsible for scheduling the burst. You need to drive an extra pair of signals, Start of Burst (SOB) and End of Burst (EOB), to indicate the burst boundary. You can send the traffic in packet order or interleaved order, as long as you set the SOB and EOB flags correctly to establish the data boundaries.

Figure 6. Packet Transfer on Transmit Interface in Interleaved Single Segment Mode

The figure shows the timing diagram for an interleaved data transfer (8-word) in Interleaved mode.



This example illustrates the expected behavior of the Interlaken IP core application interface transmit signals during data transfers from the application to the IP core on the TX user data transfer interface in interleaved single segment mode.

In cycle 1, the application asserts `itx_sop[1]` and `itx_sob[1]`, indicating that this cycle is both the start of the burst and the start of the packet. The value the application drives on `itx_chan` indicates the data originates from channel 2.

In cycle 2, the application asserts `itx_eob`, indicating the data the application transfers to the IP core in this clock cycle is the end of the burst. (`itx_chan` only needs to be valid when `itx_sob[1]` or `itx_sop[1]` is asserted).

`itx_num_valid[7:4]` indicates all eight words are valid. However, the data in this cycle is not end of packet data. The application is expected to transfer at least one additional data burst in this packet, possibly interleaved with one or more bursts in packets from different data channels.

Cycle 3 is a short burst with both `itx_sob[1]` and `itx_eob` asserted. The application drives the value of three on `itx_num_valid[7:4]` to indicate that three words of the eight-word `itx_din_words` data bus are valid. The data is packed in the most significant words of `itx_din_words`. The application drives the value of `4'b1011` on `itx_eopbits` to indicate that the data the application transfers to the IP core in this cycle are the final words of the packet, and that in the final word of the packet, only three bytes are valid data. The value the application drives on `itx_chan` indicates this burst originates from channel 4.

In cycle 4, the `itx_num_valid[7:4]` signal has the value of zero, which means this cycle is an idle cycle.

In cycle 5, the application sends another single-cycle data burst from channel 2, by asserting `itx_sob[1]` and `itx_eob` to indicate this data is both the start and end of the burst. The application does not assert `itx_sop[1]`, because this burst is not start



of packet data. `itx_eopbits` has the value of `4'b0000`, indicating this burst is also not end of packet data. This data follows the data burst transferred in cycles 1 and 2, within the same packet from channel 2.

In cycle 6, the application sends a start of packet, single-cycle data burst from channel 3.

In cycles 7 and 8, the application sends a two-cycle data packet in one two-cycle burst. In cycle 8, the second data cycle, the application drives the value of two on `itx_num_valid[7:4]` and the value of `4'b1011` on `itx_eopbits`, to tell the IP core that in this clock cycle, the two most significant words of the data symbol contain valid data and the remaining words do not contain valid data, and that in the second of these two words, only the three most significant bytes contain valid data.

In Interleaved Mode, you can transfer a packet without interleaving as long as the channel number does not toggle during the same packet transfer. However, you must still assert the `itx_sob` and `itx_eob` signals correctly to maintain the proper burst boundaries.

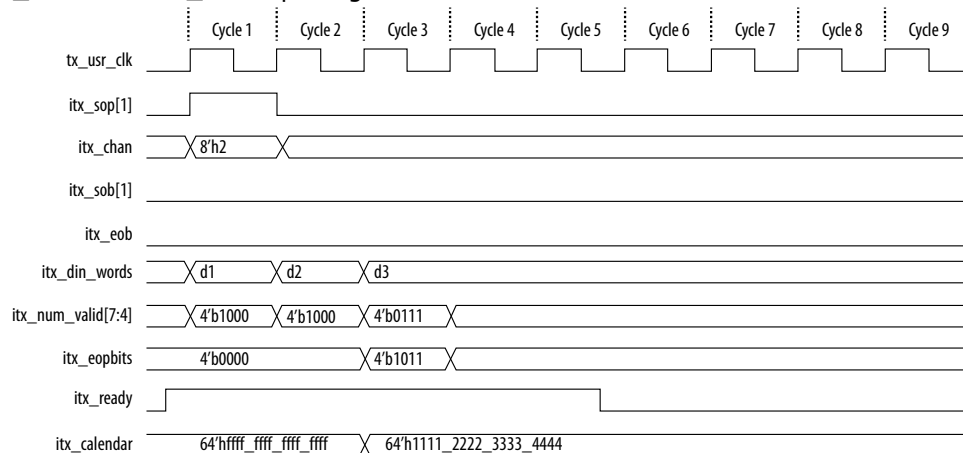
If you do not drive the `itx_sob` and `itx_eob` signals, the Interlaken IP Core does not operate properly and the transmit FIFO may overflow, since in this mode the internal logic is looking for `itx_sob` and `itx_eob` assertion for insertion of proper burst control words.

Packet Mode Operation Example

This example illustrates the expected behavior of the Interlaken IP core application interface transmit signals during a packet transfer in single segment packet mode.

Figure 7. Packet Transfer on Transmit Interface in Packet Mode

The figure illustrates a packet mode data transfer (8-word) of 179 bytes on the transmit interface into the IP core. In this mode, the Interlaken IP core ignores the `itx_sob` and `itx_eob` input signals.



To start a transfer, you assert `itx_sop[1]` when you have data ready on `itx_din_words`. At the following rising edge of the clock, the IP core detects that `itx_sop[1]` is asserted, indicating that the value on `itx_din_words` in the current cycle is the start of an incoming data packet. When you assert `itx_sop[1]`, you



must also assert the correct value on `itx_chan` to tell the IP core the data channel source of the data. In this example, the value 2 on `itx_chan` tells the IP core that the data originates from channel number 2.

During the SOP cycle (labeled with data value `d1`) and the cycle that follows the SOP cycle (labeled with data value `d2`), you must hold the value of `itx_num_valid[7:4]` at `4'b1000`. In the following clock cycle, labeled with data value `d3`, you must hold the following values on critical input signals to the IP core:

- `itx_num_valid[7:4]` at the value of `4'b0111` to indicate the current data symbol contains seven 64-bit words of valid data.
- `itx_eopbits[3]` high to indicate the current cycle is an EOP cycle.
- `itx_eopbits[2:0]` at the value of `3'b011` to indicate that only three bytes of the final valid data word are valid data bytes.

This signal behavior correctly transfers a data packet with the total packet length of 179 bytes to the IP core, as follows:

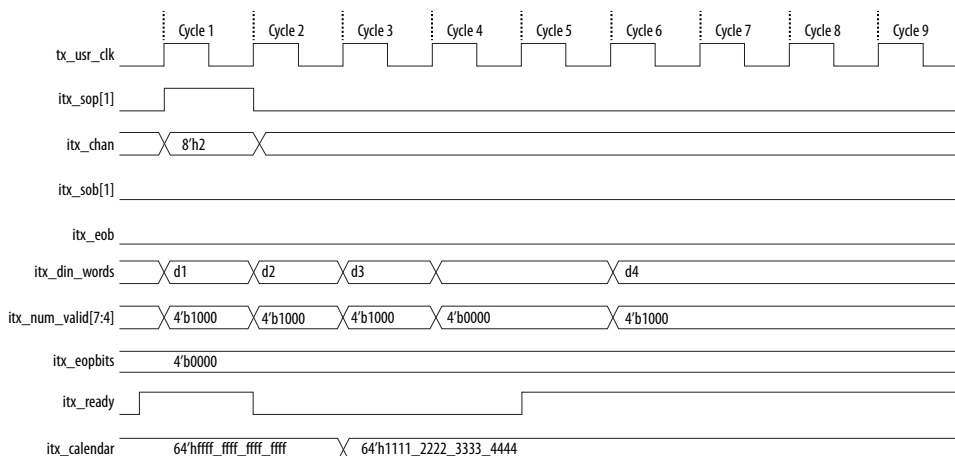
- In the SOP cycle, the IP core receives 64 bytes of valid data (`d1`).
- In the following clock cycle, the IP core receives another 64 bytes of valid data (`d2`).
- In the third clock cycle, the EOP cycle, the IP core receives 6 full words ($6 \times 8 = 48$ bytes) and three bytes of valid data, for a total of 51 valid bytes.

The total packet length is $64 + 64 + 51 = 179$ bytes.

Back-Pressured Packet Transfer Example

This example illustrates the expected behavior of the Interlaken application interface transmit signals during a packet transfer with back pressure.

Figure 8. Packet Transfer on Transmit Interface with Back Pressure



In this example, the Interlaken IP core accepts the first four data symbols (256 bytes) of a data packet. The clock cycles in which the application transfers the data values `d2` and `d3` to the Interlaken IP Core are grace-period cycles following the Interlaken IP core's de-assertion of `itx_ready`.

The Interlaken IP core supports up to 4 cycles of grace period, enabling you to register the input data and control signals, as well as the `itx_ready` signal, without changing functionality. The grace period supports your design in achieving timing closure more easily. In any case you must ensure that you hold `itx_num_valid` at the value of 0 when you are not driving data.

You can think of this interface as a FIFO write interface. When `itx_num_valid[7:4]` is nonzero, both data and control information (including `itx_num_valid[7:4]` itself) are written to the transmit side data interface. The `itx_ready` signal is the inverse of a hypothetical FIFO-almost-full flag. When `itx_ready` is high, the Interlaken IP core is ready to accept data. When `itx_ready` is low, you can continue to send data for another 6 to 8 clock cycles of `tx_usr_clk`.

4.4.2 Interlaken RX Path

The Interlaken IP core receives data on the Interlaken link, monitors and removes Interlaken overhead, and provides user data and calendar information to the application. Calendar information is available only if you turn on Include in-band flow control block in the Interlaken parameter editor.

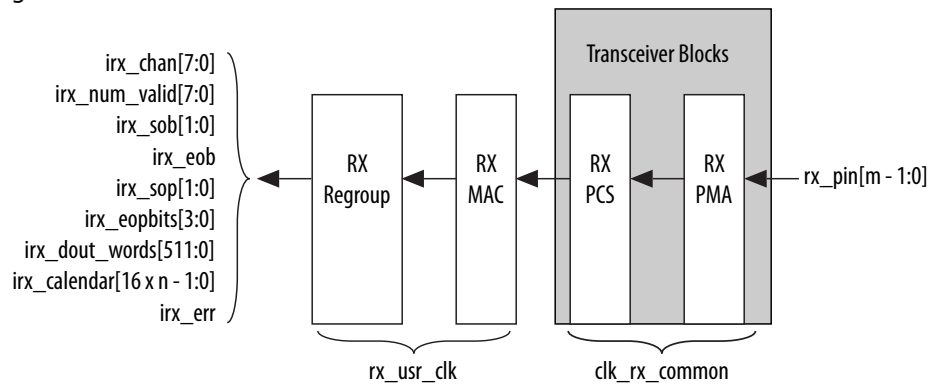
4.4.2.1 Receive Path Blocks

The Interlaken IP core receive data path has the following four main functional blocks:

- RX PMA
- RX PCS
- RX MAC
- RX Regroup Block

Figure 9. Interlaken IP Core Receive Path Blocks

The figure illustrates the 8-word data transfer scenario.



RX PMA

The Interlaken IP core RX PMA deserializes data that the IP core receives on the serial lines of the Interlaken link.



RX PCS

RX PCS logic is an embedded hard macro and does not consume FPGA soft logic elements. The Interlaken IP core RX PCS block performs the following functions to retrieve the data:

- Detects word lock and word synchronization.
- Checks running disparity.
- Reverses gear-boxing and 64/67B encoding.
- Descrambles the data.
- Delineates meta frame boundaries.
- Performs CRC32 checking.
- Sends lane status information to the calendar and status blocks, if **Include in-band flow control functionality** is turned on.

RX MAC

To recover a packet or burst, the RX MAC takes data from each of the PCS lanes and reassembles the packet or burst. The Interlaken IP core RX MAC performs the following functions:

- Data de-stripping, including lane alignment and burst assembly from the PCS lanes.
- CRC24 validation.
- Calendar recovery, if **Include in-band flow control functionality** is turned on.

RX Regroup Block

The Interlaken IP core RX regroup block translates the IP core internal data format to the outgoing user application data `irx_data` format.

4.4.2.2 In-Band Calendar Bits on Receive Side

The Interlaken IP core receiver logic decodes incoming control words (both Burst control words and Idle control words) on the incoming Interlaken link. If you turn on **Include in-band flow control functionality**, the receiver logic extracts the calendar pages from the In-Band Flow Control bits and assembles them into the `irx_calendar` output signal. If you turn off **Include in-band flow control functionality**, the IP core sets all the bits of `irx_calendar` to the value of 1, indicating that the IP core is not flow controlling the incoming data on the Interlaken link.

The Interlaken IP core receives the most significant calendar page in a control word with the Reset Calendar bit set, indicating the beginning of the calendar page sequence. The mapping of bits from the control words to the `irx_calendar` output signal is consistent with the mapping of bits from the `itx_calendar` input signal to the control words.

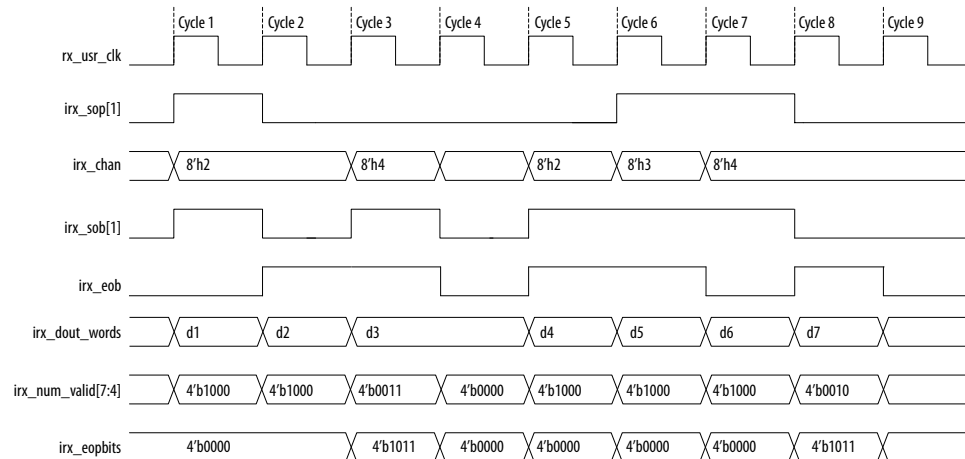
On the RX side, your application is responsible for mapping the calendar pages to the corresponding channels, according to any interpretation agreed upon with the Interlaken link partner application in sideband communication. On the TX side, your application is responsible for throttling the data it transfers to the TX user data transfer interface, in response to the agreed upon interpretation of the `irx_calendar` bits.

4.4.2.3 Receive User Data Interface Example

The Interlaken IP Core can generate interleaved data transfers on the RX user data transfer interface. The IP core always toggles the `irx_sob` and `irx_eob` signals to indicate the beginning of the burst and end of the burst. In single segment mode, only `irx_sob[1]` toggles. In dual segment mode, `irx_sob[0]` toggles if the current burst starts at word 4 of the data symbol.

Figure 10. Interlaken IP Core Receiver Side Single Segment Example

The figure shows the timing diagram for an interleaved data transfer (8-word) in Interleaved mode.



This example illustrates the expected behavior of the Interlaken IP core application interface receive signals during data transfers from the IP core to the application on the RX user data transfer interface in interleaved single segment mode.

In cycle 1, the IP core asserts `irx_sop[1]` and `irx_sob[1]`, indicating that this cycle is both the start of the burst and the start of the packet. The first word is MSB aligned at the top. The value the IP core drives on `irx_chan` indicates the data targets channel 2. You must sample `irx_chan` during cycles in which `irx_sop[1]` is asserted. The `irx_chan` output signal is not guaranteed to remain valid for the duration of the burst.

In cycle 2, the IP core asserts `irx_eob`, indicating the data the IP core transfers to the application in this clock cycle is the end of the burst. `irx_num_valid[7:4]` indicates all eight words are valid. However, the data in this cycle is not end of packet data. The IP core will transfer at least one additional data burst in this packet, possibly interleaved with one or more bursts in packets that target different data channels.

Cycle 3 is a short burst with both `irx_sop[1]` and `irx_eob` asserted. The IP core drives the value of three on `irx_num_valid[7:4]` to indicate that three words of the eight-word `irx_dout_words` data bus are valid. The data is packed in the most significant words of `irx_dout_words`. The IP core drives the value of `4'b1011` on `irx_eopbits` to indicate that the data the IP core transfers to the application in this cycle are the final words of the packet, and that in the final word of the packet, only three bytes are valid data. The value the IP core drives on `irx_chan` indicates this burst targets channel 4.



In cycle 4, the `irx_num_valid[7:4]` signal has the value of zero, which means this cycle is an idle cycle.

In cycle 5, the IP core sends another single-cycle data burst to channel 2, by asserting `irx_sob[1]` and `irx_eob` to indicate this data is both the start and end of the burst. The IP core does not assert `irx_sop[1]`, because this burst is not start of packet data. `irx_eopbits` has the value of `4'b0000`, indicating this burst is also not end of packet data. This data follows the data burst transferred in cycles 1 and 2, within the same packet the IP core is sending to channel 2.

In cycle 6, the IP core sends a start of packet, single-cycle data burst to channel 3.

In cycles 7 and 8, the IP core sends a two-cycle data packet in one two-cycle burst. In cycle 8, the second data cycle, the IP core drives the value of two on `irx_num_valid[7:4]` and the value of `4'b1011` on `irx_eopbits`, to tell the application that in this clock cycle, the two most significant words of the data symbol contain valid data and the remaining words do not contain valid data, and that in the second of these two words, only the three most significant bytes contain valid data.

4.4.2.4 RX Errored Packet Handling

The Interlaken IP Core provides information about errored packets on the RX user data transfer interface through the following output signals:

- `irx_eopbits[3:0]`—If this signal has the value of `4'b0001`, an error indication arrived with the packet on the incoming Interlaken link: the `EOP_Format` field of the control word following the final burst of the packet on the Interlaken link has this value, which indicates an error and EOP.
- `irx_err`— The Interlaken IP Core checks the integrity of incoming packets on the Interlaken link, and reports some packet corruption errors it detects on the RX user data transfer interface in the `irx_err` output signal. The IP core asserts the `irx_err` output signal synchronously with the `irx_eob` signal. The IP core asserts this signal only if it can determine the burst in which the error occurred. If the IP core cannot determine the burst in which the error occurred, it does not assert the `irx_err` in response.

In both cases, the application is responsible for discarding the relevant packet.

The `irx_err` signal reflects CRC24 errors that are associated with a data or control burst and is aligned with `irx_eob`.

The `irx_err` signal indicates where an error occurs. The IP core asserts this signal only if an error occurs in an identifiable burst. Corruption can occur at the SOP of the current packet, in some later cycle in the payload of the current packet, in a packet that is interleaved with the current packet, or in the current EOP cycle. However, the IP core asserts the `irx_err` signal only in a subset of these cases, If the current EOP cycle data is corrupted so badly that the EOP indication is missing, or if an error occurs during an IDLE cycle, the IP core does not assert the `irx_err` signal.



For CRC24 errors, you should use the `crc24_err` status signal, rather than relying on the `irx_err` signal, in the following situations:

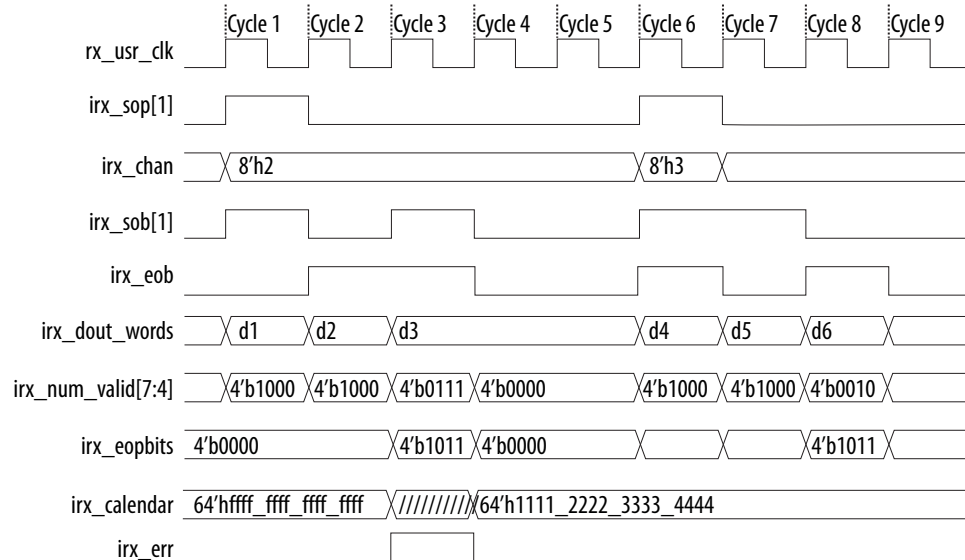
- If you monitor the link when only Idle control words are being received (no data is flowing), you should monitor the real time status signal `crc24_err`.
- If you maintain a count of CRC24 errors, you should monitor the number of times that the real time status signal `crc24_err` is asserted.

4.4.2.4.1 Example With Errors and In-Band Calendar Bits

This example illustrates the expected behavior of the Interlaken IP core application interface receive signals during a packet transfer in single segment mode with CRC or other errors. In the example, the errored packet transfer is followed by two idle cycles and a non-errored packet transfer.

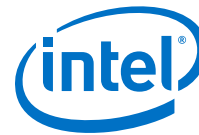
Figure 11. Interlaken IP Core Receiver Side Single Segment Example With `irx_err` Errors

This figure illustrates the attempted transfer of a 179-byte packet on the RX user data transfer interface to channel 2, after the Interlaken IP core receives the packet on the Interlaken link and detects corruption. Following the errored packet, the IP core transfers an uncorrupted packet to channel 3.



In cycle 1, the Interlaken IP core asserts `irx_sop[1]` when data is ready on `irx_dout_words`. When the Interlaken IP core asserts `irx_sop[1]`, it also asserts the correct value on `irx_chan` to tell the application the data channel destination of the data. In this example, the value 2 on `irx_chan` tells the application that the data should be sent to channel number 2.

During the SOP cycle (labeled with data value d1) and the cycle that follows the SOP cycle (labeled with data value d2), the Interlaken IP core holds the value of `irx_num_valid[7:4]` at 4'b1000. In the following clock cycle, labeled with data value d3, the Interlaken IP core holds the following values on critical output signals:



- `irx_num_valid[7:4]` at the value of `4'b0111` to indicate the current data symbol contains seven 64-bit words of valid data.
- `irx_eopbits[3]` high to indicate the current cycle is an EOP cycle.
- `irx_eopbits[2:0]` at the value of `3'b011` to indicate that only three bytes of the final valid data word are valid data bytes.

This signal behavior, in the absence of the `irx_err` flag, would correctly transfer a data packet with the total packet length of 179 bytes from the Interlaken IP core. However, the Interlaken IP core marks the burst as errored by asserting the `irx_err` signal, even though the `irx_eopbits` signal would appear to indicate the packet is valid.

The application is responsible for discarding the errored packet when it detects that the IP core has asserted the `irx_err` signal. Following the corrupted packet, the IP core waits two idle cycles and then transfers a valid 139-byte packet.

4.5 IP Core Reset

The Interlaken IP core variations have a single asynchronous reset, the `reset_n` signal. The Interlaken IP core manages the initialization sequence internally. After you de-assert `reset_n` (raise it after asserting it low), the IP core automatically goes through the entire reset sequence.

Note: Intel recommends that you hold the `reset_n` signal low for at least the duration of two `mm_clk` cycles, to ensure the reset sequence proceeds correctly.

Following completion of the reset sequence internally, the Interlaken IP core begins link initialization. If your IP core and its Interlaken link partner initialize the link successfully, you can observe the assertion of the lane and link status signals according to the Interlaken specification. For example, you can monitor the `tx_lanes_aligned`, `sync_locked`, `word_locked`, and `rx_lanes_aligned` output status signals.

In Stratix 10 devices, the required wait time from de-asserting the `reset_n` signal to safely accessing the IP core registers is a function of the internal reset controller.

Related Links

- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

4.6 M20K ECC Support

If you turn on **Enable M20K ECC support** in your Stratix 10 Interlaken IP core variation, the IP core takes advantage of the built-in device support for ECC checking in all M20K blocks configured in the IP core on the device. The feature performs single-error correct, double-adjacent-error correct, and triple-adjacent-error detect ECC functionality in the M20K memory blocks configured in your IP core.

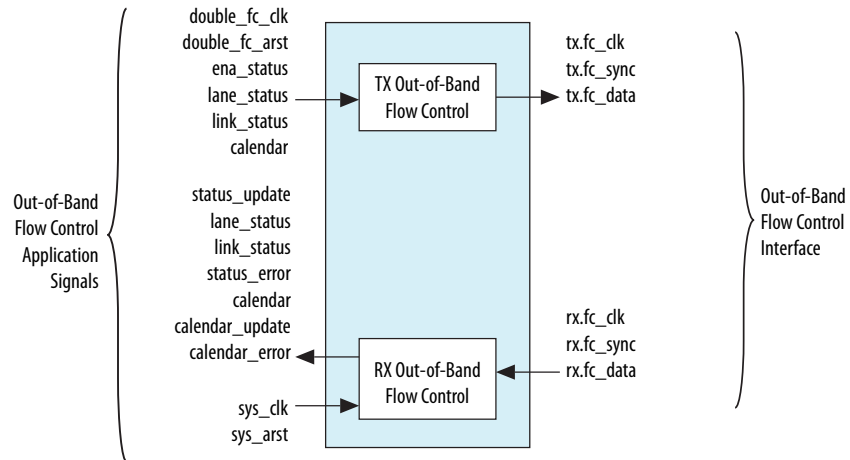
This feature enhances data reliability but increases latency and resource utilization. Without the ECC feature, a single M20K memory block can support a data path width of 40 bits. With the ECC feature, eight of those bits are dedicated to the ECC, and an M20K memory block can support a maximum data path width of 32 bits. Therefore, when M20K ECC support is turned on the IP core configures additional M20K memory blocks. The ECC check adds latency to the path through the memory block, and increases the amount of device memory used by your IP core.

4.7 Out-of-Band Flow Control

The Interlaken IP core includes logic to provide the out-of-band flow control functionality described in the *Interlaken Protocol Specification, Revision 1.2*, Section 5.3.4.2. This optional feature is intended for applications that require transmission rate control.

Figure 12. Out-of-Band Flow Control Block Interface

This figure lists the signals on the four interfaces of the out-of-band flow control block.



The out-of-band flow control block is provided as two separate modules that can be stitched to the Interlaken IP core and user logic. You can optionally instantiate these blocks in your own custom logic. To enable the use of these out-of-band modules, the signals on the far left side of the figure must be connected to user logic, and the signals on the far right side of the figure should be connected to the complementary flow control blocks of the Interlaken link partner.

You must connect the out-of-band flow control receive and transmit interface signals to device pins.

Table 11. Out-of-Band Flow Control Block Clocks

Clock Name	Interface	Direction	Recommended Frequency (MHz)	Description
RX_fc_clk	RX Out-of-band	Input	100	Clocks the incoming out-of-band flow control interface signals described in the Interlaken specification. This clock is received from an upstream TX out-of-band flow control block associated with the Interlaken link

continued...



Clock Name	Interface	Direction	Recommended Frequency (MHz)	Description
				partner. The recommended frequency for the RX <code>fc_clk</code> clock is 100 MHz, which is the maximum frequency allowed by the Interlaken specification.
TX <code>fc_clk</code>	TX Out-of-band	Output	100	Clocks the outgoing out-of-band flow control interface signals described in the Interlaken specification. This clock is generated by the out-of-band flow control block and sent to a downstream RX out-of-band flow control block associated with the Interlaken link partner. The frequency of this clock must be half the frequency of the <code>double_fc_clk</code> clock. The recommended frequency for the TX <code>fc_clk</code> clock is 100 MHz, which is the maximum frequency allowed by the Interlaken specification.
<code>sys_clk</code>	RX Application	Input	200	Clocks the outgoing calendar and status information on the application side of the block. The frequency of this clock must be at least double the frequency of the RX input clock <code>fc_clk</code> . Therefore, the recommended frequency for the <code>sys_clk</code> clock is 200 MHz.
<code>double_fc_clk</code>	TX Application	Input	200	Clocks the incoming calendar and status information on the application side of the block. The frequency of this clock must be double the frequency of the TX output clock <code>fc_clk</code> . Therefore, the recommended frequency for the <code>double_fc_clk</code> clock is 200 MHz.

The transmit out-of-band flow control interface receives calendar and status information, and transmits flow control clock, data, and sync signals. The TX Out-of-Band Flow Control Interface Signals table describes the transmit out-of-band flow control interface signals specified in the *Interlaken Protocol Specification, Revision 1.2*. The TX Out-of-Band Flow Control Block Signals for Application Use table describes the signals on the application side of the TX out-of-band flow control block.

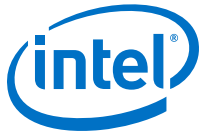
Table 12. TX Out-of-Band Flow Control Interface Signals

Signal Name	Direction	Width (Bits)	Description
<code>fc_clk</code>	Output	1	Output reference clock to a downstream out-of-band RX block. Clocks the <code>fc_data</code> and <code>fc_sync</code> signals. You must connect this signal to a device pin.
<code>fc_data</code>	Output	1	Output serial data pin to a downstream out-of-band RX block. You must connect this signal to a device pin.
<code>fc_sync</code>	Output	1	Output sync control pin to a downstream out-of-band RX block. You must connect this signal to a device pin.

Table 13. TX Out-of-Band Flow Control Block Signals for Application Use

Signal Name	Direction	Width (Bits)	Description
<code>double_fc_clk</code>	Input	1	Reference clock for generating the flow control output clock <code>fc_clk</code> . The frequency of the <code>double_fc_clk</code> clock must be double the intended frequency of the TX <code>fc_clk</code> output clock.
<code>double_fc_arst</code>	Input	1	Asynchronous reset for the out-of-band TX block.

continued...



Signal Name	Direction	Width (Bits)	Description
ena_status	Input	1	Enable transmission of the lane status and link status to the downstream out-of-band RX block. If this signal is asserted, the lane and link status information is transmitted on fc_data. If this signal is not asserted, only the calendar information is transmitted on fc_data.
lane_status	Input	Number of Lanes	Lane status to be transmitted to a downstream out-of-band RX block if ena_status is asserted. Width is the number of lanes.
link_status	Input	1	Link status to be transmitted to a downstream out-of-band RX block if ena_status is asserted.
calendar	Input	16	Calendar status to be transmitted to a downstream out-of-band RX block.

The receive out-of-band flow control interface receives input flow control clock, data, and sync signals and sends out calendar and status information. The RX Out-of-Band Flow Control Interface Signals table describes the receive out-of-band flow control interface signals specified in the *Interlaken Protocol Specification, Revision 1.2*. The *RX Out-of-Band Flow Control Block Signals for Application Use* describes the signals on the application side of the RX out-of-band flow control block.

Table 14. RX Out-of-Band Flow Control Interface Signals

Signal Name	Direction	Width (Bits)	Description
fc_clk	Input	1	Input reference clock from an upstream out-of-band TX block. This signal clocks the fc_data and fc_sync signals. You must connect this signal to a device pin.
fc_data	Input	1	Input serial data pin from an upstream out-of-band TX block. You must connect this signal to a device pin.
fc_sync	Input	1	Input sync control pin from an upstream out-of-band TX block. You must connect this signal to a device pin.

Table 15. RX Out-of-Band Flow Control Block Signals for Application Use

Signal Name	Direction	Width (Bits)	Description
sys_clk	Input	1	Reference clock for capturing RX calendar, lane status, and link status. Frequency must be at least double the frequency of the TX fc_clk input clock.
sys_arst	Input	1	Asynchronous reset for the out-of-band RX block.
status_update	Output	1	Indicates a new value without CRC4 errors is present on at least one of lane_status or link_status in the current sys_clk cycle. The value is ready to be read by the application logic.
lane_status	Output	Number of Lanes	Lane status bits received from an upstream out-of-band TX block on fc_data. Width is the number of lanes.
link_status	Output	1	Link status bit received from an upstream out-of-band TX block on fc_data.
status_error	Output	1	Indicates corrupt lane or link status. A new value is present on at least one of lane_status or link_status in the current sys_clk cycle, but the value has at least one CRC4 error.
<i>continued...</i>			

4 Functional Description



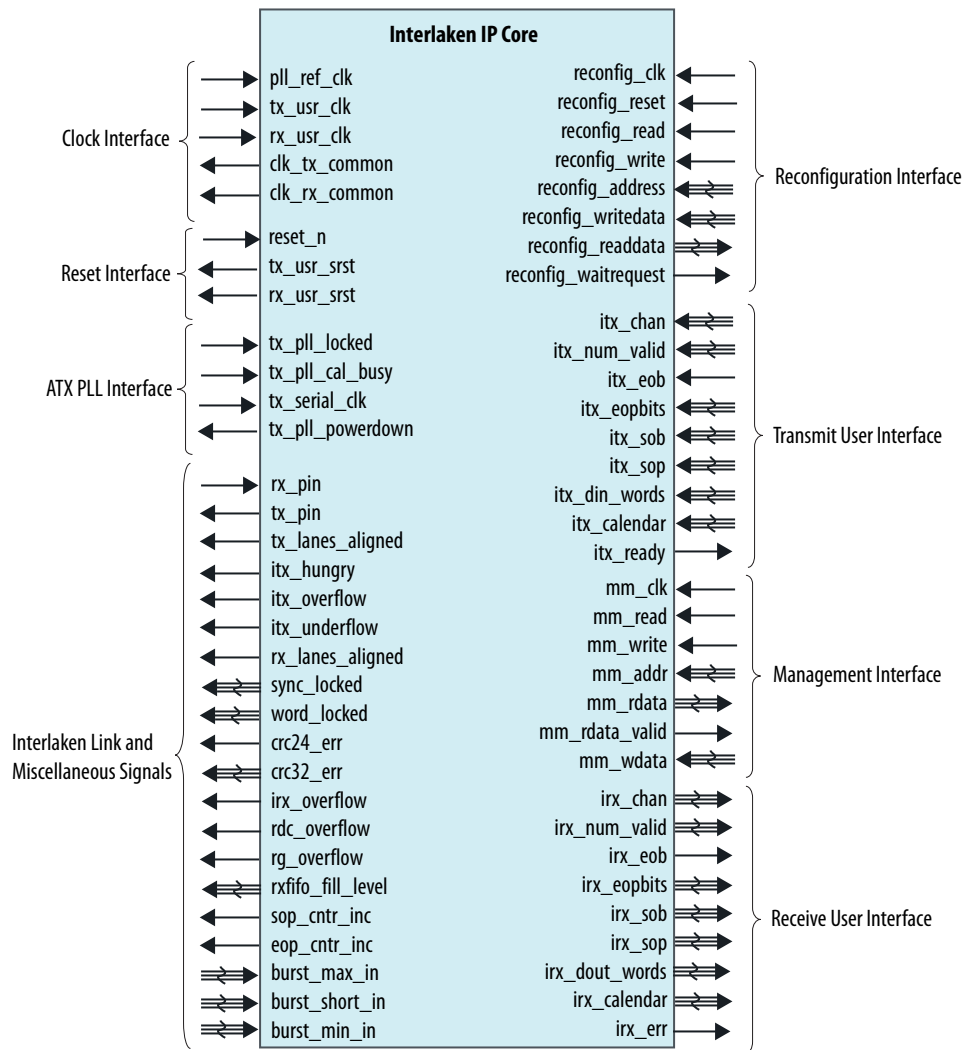
Signal Name	Direction	Width (Bits)	Description
calendar	Output	16	Calendar bits received from an upstream out-of-band TX block on <code>fc_data</code> .
calendar_update	Output	1	Indicates a new value without CRC4 errors is present on calendar in the current <code>sys_clk</code> cycle. The value is ready to be read by the application logic.
calendar_error	Output	1	Indicates corrupt calendar bits. A new value is present calendar in the current <code>sys_clk</code> cycle, but the value has at least one CRC4 error.



5 Interface Signals

The IP core communicates with the surrounding design through multiple external signals.

Figure 13. IP Core Interface Signals





5.1 Clock and Reset Interface Signals

Table 16. Clock and Reset Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description	
pll_ref_clk	1	Input	Transceiver reference clock for the RX CDR PLL in IP core variations that target a Stratix 10 device. The sets of valid frequencies vary with the per-lane data rate of the transceivers as following:	
			Per-Lane Data Rate (Gbps)	Valid pll_ref_clk Frequencies (MHz)
			10.3125	206.25, 257.8125, 322.265625, 412.5, 515.625, 644.53125
			12.5/6.25	156.25, 195.3125, 250, 312.5, 390.625, 500, 625
	25.3	126.4, 158.0, 197.5, 252.8, 320.0, 395.0, 412.5, 505.6		
tx_usr_clk	1	Input	Transmit side user data interface clock. This signal must be driven by clk_tx_common for maximum performance. The lower frequency of tx_clk increases the latency of data path.	
rx_usr_clk	1	Input	Receive side user data interface clock. This signal must be driven by clk_rx_common for maximum performance. The lower frequency of rx_clk increases the latency of data path.	
clk_tx_common	1	Output	Transmit PCS common lane clock driven by the SERDES transmit PLL. The frequency is given by the following equation: Frequency of clk_tx_common = transceiver data rate / PMA_WIDTH For example, the clock rate is 322 MHz at 10.3125 Gbps transceiver speed with 32 bits PMA_WIDTH.	
clk_rx_common	1	Output	Receive PCS common lane clock driven by CDR in transceiver. The frequency is given by the following equation: Frequency of clk_rx_common = transceiver data rate / PMA_WIDTH For example, the clock rate is 322 MHz at 10.3125 Gbps transceiver speed with 32 bits PMA_WIDTH.	
reset_n	1	Input	Active-low asynchronous reset signal.	
tx_usr_srst	1	Output	Transmit side reset output signal. Indicates the transmit side user data interface is resetting. This signal is synchronous with tx_usr_clk.	
rx_usr_srst	1	Output	Receive side reset output. Indicates the receive side user data interface is resetting. This signal is synchronous with rx_usr_clk.	

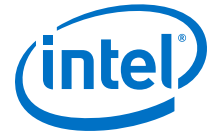
Related Links

- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

5.2 Transmit User Interface Signals

Table 17. Transmit User Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description
itx_chan	8	Input	Transmit logic channel number. The IP core supports up to 256 channels. The IP core samples this value only when a bit of <code>itx_sop</code> or <code>itx_sob</code> is high and <code>itx_num_valid</code> has a non-zero value.
itx_num_valid	Variable	Input	<p>Indicates the number of valid 64-bit words in the current packet in the current data symbol. The width of the <code>itx_num_valid</code> depends on the parameter <code>internal_words</code>.</p> <ul style="list-style-type: none"> If <code>internal_words=4</code>, then width=3 bits. If <code>internal_words=8</code>, then width=8 bits. If <code>internal_words=16</code>, then width=10 bits. <p>If <code>internal_words</code> is equal to 8:</p> <ul style="list-style-type: none"> <code>itx_num_valid[7:4]</code> indicates the number of valid words in <code>itx_din_words[511:0]</code>. The value can vary from 4'b0000 to 4'b1000. <code>itx_num_valid[3:0]</code> indicates the number of valid words in <code>itx_din_words[255:0]</code>. The value must be either 4'b0100 or 4'b0000. When <code>itx_num_valid[3:0]</code> has the value of 4'b0100, you must also hold <code>itx_sop[0]</code> high. <p>When <code>itx_ready</code> is not asserted, it is non-valid cycle, hence the value of <code>itx_num_valid[7:4]</code> and <code>itx_num_valid[3:0]</code> must be set to 4'b0000.</p> <p>In valid cycles, you must set the value of <code>itx_num_valid[7:4]</code> as following:</p> <ul style="list-style-type: none"> 4'b1000: if all eight words contain valid data from the current packet. 4'b0xxx: where xxx indicates the number of valid words that are part of the current packet, if the number is less than eight. Data is always MSB aligned (left aligned). For example, the value of 4'b0111 indicates that word 0 (bit [63:0]) is not valid. <p>In dual segment mode, if the value of <code>itx_num_valid[7:4]</code> is four or less (but not zero), the application can hold <code>itx_num_valid[2]</code> high to indicate the current data symbol also includes the first four 64-bit words of a new packet.</p>
itx_eob	1	Input	<p>Indicates the current data symbol contains the end of the burst (EOB). When <code>itx_eopbits[3]</code> or <code>itx_eopbits[0]</code> is valid, the <code>itx_eob</code> is valid too, but not vice-versa.</p> <p>Whenever parameter <code>TX_PKTMOD_ONLY</code> is set to 0, you must provide this signal. Otherwise, when parameter <code>TX_PKTMOD_ONLY</code> is set to 1, the IP core will ignore this signal. You are responsible to comply with the BurstMax and BurstMin setting.</p>
itx_eopbits	4	Input	<p>Indicates whether the current data symbol contains the end of a packet (EOP) with or without an error, and specifies the number of valid bytes in the current end-of-packet, non-error 8-byte data word, if relevant.</p> <p>You must set the value of <code>itx_eopbits</code> as following:</p> <ul style="list-style-type: none"> 4b'0000: no end of packet, no error. 4b'0001: Error and end of packet. 4b'1xxx: End of packet. xxx indicates the number of valid bytes in the final valid 8-byte word of the packet, as following: <ul style="list-style-type: none"> 000: all 8 bytes are valid. 001: 1 byte is valid. ... 111: 7 bytes are valid. <p>All other values (4'b01xx, 4'b001x) are undefined. The valid bytes always start in bit positions [63:56] of the final valid data word of the packet.</p>
			<i>continued...</i>



Signal Name	Width (Bits)	I/O Direction	Description
itx_sob	2 (or 1 for 4-word use case)	Input	<p>Indicates the current data symbol contains the start of a burst (SOB). If the IP core is in Interleaved mode, you are responsible for providing this start of the burst signal. If the IP core is in Packet mode, the IP core ignores this signal. The IP core samples the <code>itx_chan</code> signal during this cycle.</p> <p>This signal has the following valid values:</p> <ul style="list-style-type: none"> 2'b00—The current data symbol does not contain the start of a burst. 2'b10— If <code>itx_sob[1]</code> has the value of 1, the start-of-burst aligns with the most significant byte (byte 63) of the data. 2'b01— If <code>itx_sob[0]</code> has the value of 1, the start-of-burst aligns with byte 31 of the data. <p>Typically, you use this mode for sending interleaved packets. However, you can still send non-interleaved packets as long as you provide the <code>itx_sob</code> and <code>itx_eob</code> signal values. You are responsible to comply with the BurstMax and BurstMin setting. If the burst you send is too large, it can overflow the Interlaken transmit buffer.</p>
itx_sop	2 (or 1 for 4-word use case)	Input	<p>Indicates the current data symbol on <code>itx_din_words</code> contains the start of a packet (SOP). This signal has the following valid values:</p> <ul style="list-style-type: none"> 2'b00—The current data symbol does not contain the start of a packet. 2'b10— If <code>itx_sop[1]</code> has the value of 1, the start-of-packet aligns with the most significant byte (byte 63) of the data. 2'b01— If <code>itx_sop[0]</code> has the value of 1, the start-of-packet aligns with byte 31 of the data.
itx_din_words	Variable	Input	<p>The 64-bit words of input data (one data symbol). The width of the <code>itx_dout_words</code> depends on the parameter <code>internal_words</code>.</p> <ul style="list-style-type: none"> If <code>internal_words=4</code>, then width=256 bits. If <code>internal_words=8</code>, then width=512 bits. If <code>internal_words=16</code>, then width=1024 bits. <p>When <code>tx_idle</code> or <code>tx_sob</code> is one, the Interlaken IP core ignores matching data word in <code>tx_data</code>. The first and last data word is in [511:448] and [63:0] respectively.</p>
itx_calendar	N * 16	Input	<p>Multiple pages (16 bits per page) of calendar input bits. The IP core copies these bits to the in-band flow control bits in N control words that it sends on the Interlaken link. N is the value of the Number of calendar pages parameter, which can be any of 1, 2, 4, 8, or 16. This signal is synchronous with <code>tx_usr_clk</code>, although it is not part of the user data transfer protocol.</p>
itx_ready	1	Output	<p>Flow control signal to back pressure transmit traffic. When this signal is high, you can send traffic to the IP core. When this signal is low, you should stop sending traffic to the IP core within one to four cycles. You should provide <code>itx_num_valid</code> only after <code>itx_ready</code> is asserted.</p>

5.3 Receive User Interface Signals

Table 18. Receive User Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description
irx_chan	8	Output	<p>Receive logic channel number. The IP core supports up to 256 channels. The Interlaken IP core samples this value only when a bit of <code>irx_sop</code> or <code>irx_sob</code> is high and <code>irx_num_valid</code> has a non-zero value.</p>
irx_num_valid	Variable	Output	<p>Indicates the number of valid 64-bit words in the current packet in the current data symbol. The width of the <code>irx_num_valid</code> depends on the parameter <code>internal_words</code>.</p>

continued...



Signal Name	Width (Bits)	I/O Direction	Description
			<ul style="list-style-type: none"> If <code>internal_words=4</code>, then <code>width=3</code> bits. If <code>internal_words=8</code>, then <code>width=8</code> bits. If <code>internal_words=16</code>, then <code>width=10</code> bits. <p>If <code>internal_words</code> is equal to 8:</p> <ul style="list-style-type: none"> <code>irx_num_valid[7:4]</code> indicates the number of valid words in <code>irx_din_words[511:0]</code>. The value can vary from 4'b0000 to 4'b1000. <code>irx_num_valid[3:0]</code> indicates the number of valid words in <code>irx_din_words[255:0]</code>. The value must be either 4'b0100 or 4'b0000. When <code>irx_num_valid[3:0]</code> has the value of 4'b0100, the IP core also holds <code>itx_sop[0]</code> high. <p>For all non-valid cycles, IP core sets the value of <code>irx_num_valid[7:4]</code> and <code>irx_num_valid[3:0]</code> to 4'b0000. In valid cycles, the IP core sets the value of <code>irx_num_valid[7:4]</code> as following:</p> <ul style="list-style-type: none"> 4'b1000: if all eight words contain valid data from the current packet. 4'b0xxx: where xxx indicates the number of valid words that are part of the current packet, if the number is less than eight. Data is always MSB aligned (left aligned). For example, the value of 4'b0111 indicates that word 0 (bit [63:0]) is not valid. <p>In dual segment mode, if the value of <code>irx_num_valid[7:4]</code> is four or less (but not zero), the IP core can hold <code>irx_num_valid[2]</code> high to indicate the current data symbol also includes the first four 64-bit words of a new packet.</p>
<code>irx_eob</code>	1	Output	Indicates the end of the burst (EOB). This signal toggles in Packet Mode and in Interleaved Mode.
<code>irx_eopbits</code>	4	Output	<p>Indicates whether the current data symbol contains the end of a packet (EOP) with or without an error, and specifies the number of valid bytes in the current end-of-packet, non-error 8-byte data word, if relevant.</p> <p>IP core sets the value of <code>irx_eopbits</code> as following:</p> <ul style="list-style-type: none"> 4'b'0000: no end of packet, no error. 4'b'0001: Error and end of packet. 4'b'1xxx: End of packet. xxx indicates the number of valid bytes in the final valid 8-byte word of the packet, as following: <ul style="list-style-type: none"> 000: all 8 bytes are valid. 001: 1 byte is valid. ... 111: 7 bytes are valid. <p>All other values (4'b01xx, 4'b001x) are undefined. The valid bytes always start in bit positions [63:56] of the final valid data word of the packet.</p>
<code>irx_sob</code>	2 (or 1 for 4-word use case)	Output	<p>Indicates the start of a burst (SOB). This signal toggles in Packet Mode and in Interleaved Mode.</p> <p>This signal has the following valid values:</p> <ul style="list-style-type: none"> 2'b'00—The current data symbol does not contain the start of a burst. 2'b'10— If <code>irx_sob[1]</code> has the value of 1, the start-of-burst aligns with the most significant byte (byte 63) of the data. 2'b'01— If <code>irx_sob[0]</code> has the value of 1, the start-of-burst aligns with byte 31 of the data.
<code>irx_sop</code>	2 (or 1 for 4-word use case)	Output	Indicates the current data symbol on <code>irx_dout_words</code> contains the start of a packet (SOP). This signal has the following valid values:

continued...



Signal Name	Width (Bits)	I/O Direction	Description
			<ul style="list-style-type: none"> 2'b00—The current data symbol does not contain the start of a packet. 2'b10— If <code>irx_sop[1]</code> has the value of 1, the start-of-packet aligns with the most significant byte (byte 63) of the data. 2'b01— If <code>irx_sop[0]</code> has the value of 1, the start-of-packet aligns with byte 31 of the data.
<code>irx_dout_words</code>	Variable	Output	<p>The 64-bit words of input data (one data symbol). The width of the <code>itx_din_words</code> depends on the parameter <code>internal_words</code>.</p> <ul style="list-style-type: none"> If <code>internal_words=4</code>, then width=256 bits. If <code>internal_words=8</code>, then width=512 bits. If <code>internal_words=16</code>, then width=1024 bits. <p>When <code>rx_idle</code> or <code>rx_sob</code> is one, the matching <code>rx_data</code> words are invalid. The first and last data word is in [511:448] and [63:0] respectively. When <code>irx_num_valid</code> has the value of zero, you should ignore <code>irx_dout_words</code>.</p>
<code>irx_calendar</code>	$N * 16$	Output	<p>Multiple pages (16 bits per page) of calendar input bits. The value is the in-band flow control bits from <code>N</code> control words on the incoming Interlaken link. N is the value of the Number of calendar pages parameter, which can be any of 1, 2, 4, 8, or 16. This signal is synchronous with <code>rx_usr_clk</code>, although it is not part of the user data transfer protocol.</p>
<code>irx_err</code>	1	Output	<p>Indicates an errored packet. This signal is valid only when <code>irx_eob</code> is asserted.</p>

5.4 Management Interface Signals

Table 19. Management Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description
<code>mm_clk</code>	1	Input	Management clock. Clocks the register accesses. It is also used for clock rate monitoring and some analog calibration procedures. You must run this clock at a frequency in the range of 100 MHz–125 MHz.
<code>mm_read</code>	1	Input	Read access to the register ports.
<code>mm_write</code>	1	Input	Write access to the register ports.
<code>mm_addr</code>	16	Input	Address to access the register ports.
<code>mm_rdata</code>	32	Output	When <code>mm_rdata_valid</code> is high, <code>mm_rdata</code> holds valid read data.
<code>mm_rdata_valid</code>	1	Output	Valid signal for <code>mm_rdata</code> .
<code>mm_wdata</code>	32	Input	When <code>mm_write</code> is high, <code>mm_wdata</code> holds valid write data.

5.5 Reconfiguration Interface Signals

Table 20. Reconfiguration Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description
reconfig_clk	1	Input	Stratix 10 transceiver reconfiguration interface clock.
reconfig_reset	1	Input	Active-high synchronous reset. Assert this signal to reset the Stratix 10 transceiver reconfiguration interface.
reconfig_read	1	Input	Read access to the Stratix 10 hard PCS registers.
reconfig_write	1	Input	Write access to the Stratix 10 hard PCS registers.
reconfig_address	RECONF_ADDR+10	Input	Address to access the hard PCS registers. This signal holds both the hard PCS register offset and the transceiver channel being addressed.
reconfig_writedata	32	Input	When <code>reconfig_write</code> is high, <code>reconfig_writedata</code> holds valid write data.
reconfig_readdata	32	Output	After user logic asserts the <code>reconfig_read</code> signal, when the IP core deasserts the signal, <code>reconfig_readdata</code> holds valid read data.
reconfig_waitrequest	1	Output	Busy signal for <code>reconfig_readdata</code> .

Related Links

- [Avalon Interface Specifications](#)
- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.

5.6 Interlaken Link and Miscellaneous Signals

Table 21. SERDES Pins

Signal Name	Width (Bits)	I/O Direction	Description
rx_pin	Number of lanes	Input	Each bit represents the differential pair on an RX Interlaken lane.
tx_pin	Number of lanes	Output	Each bit represents the differential pair on a TX Interlaken lane.



Table 22. Real-Time Transmitter Status Signals

Signal Name ³	Width (Bits)	I/O Direction	Description
tx_lanes_aligned	1	Output	Indicates whether all of the transmitter lanes are aligned and are ready to send traffic.
itx_overflow	1	Output	An error flag indicating that the Transmit buffer is currently overflowing. This signal is asserted for the duration of the overflow condition: it is asserted in the first clock cycle in which the overflow occurs, and remains asserted until the Transmit buffer pointers indicate that no overflow condition exists.
itx_underflow	1	Output	An error flag indicating that the Transmit buffer is currently underflowed. In normal operation, this signal may be asserted temporarily immediately after the Interlaken IP core comes out of reset. It is asserted as a single cycle wide pulse.

Table 23. Real-Time Receiver Status Signals

Signal Name ⁴	Width (Bits)	I/O Direction	Description
rx_lanes_aligned	1	Output	Indicates whether all of the receiver lanes are aligned and are ready to receive traffic.
sync_locked	Number of lanes	Output	Receive lane has locked on the remote transmitter Meta Frame. These signals are level signals: all bits are expected to stay high unless a problem occurs on the serial line.
word_locked	Number of lanes	Output	Receive lane has identified the 67-bit word boundaries in the serial stream. These signals are level signals: all bits are expected to stay high unless a problem occurs on the serial line.
crc24_err	1	Output	A CRC24 error flag covering both control word and data word. You can use this signal to count the number of CRC24 errors. This signal is asserted as a single cycle wide pulse. If the IP core detects back-to-back CRC24 errors, this signal toggles.
crc32_err	Number of lanes	Output	An error flag indicating diagnostic CRC32 failures per lane. This signal is asserted as a single cycle wide pulse. If back-to-back CRC32 errors are detected, this signal toggles.
irx_overflow	1	Output	An error flag indicating the presence of excessive jitter at the receiver side. This signal is included in the current IP core opportunistically for diagnostic purposes.
rdc_overflow	1	Output	An error flag indicating that the RX domain-crossing FIFO is currently overflowed. The RX domain-crossing FIFO transfers data from the PCS clock domain to the MAC clock domain.
rg_overflow	1	Output	An error flag indicating that the Reassembly FIFO is currently overflowed. The Reassembly FIFO is the receiver FIFO that feeds directly to the user data interface.

continued...

³ Synchronous with tx_usr_clk.

⁴ Synchronous with rx_usr_clk.



Signal Name ⁴	Width (Bits)	I/O Direction	Description
rxfifo_fill_level	RXFIFO_ADDR_WIDTH	Output	The fill level of the Reassembly FIFO, in units of 64-bit words. The width of this signal is the value of the RXFIFO_ADDR_WIDTH parameter, which is 12 by default. You can use this signal to monitor when the RX Reassembly FIFO is empty.
sop_cntr_inc	1	Output	A pulse indicating that the IP core receiver user data interface received a start-of- packet (SOP). You can use this signal to increment a count of SOPs the application observes on the receive interface.
eop_cntr_inc	1	Output	A pulse indicating that the IP core receiver user data interface received an end-of-packet (EOP). You can use this signal to increment a count of EOPs the application observes on the receive interface.

Table 24. Burst Control Settings

Signal Name	Width (Bits)	I/O Direction	Description
burst_max_in	4	Input	Encodes the BurstMax parameter for the IP core. The actual value of the BurstMax parameter must be a multiple of 64 bytes. While traffic is present, this input signal should remain static. However, when no traffic is present, you can modify the value of the <code>burst_max_in</code> signal to modify the BurstMax value of the IP core. The IP core supports the following valid values for this signal: <ul style="list-style-type: none"> 4'b0010: 128 bytes 4'b0100: 256 bytes 4'b1000: 512 bytes
burst_short_in	4	Input	Encodes the BurstShort parameter for the IP core. The IP core supports the following valid value for this parameter: <ul style="list-style-type: none"> 4'b0001: 32 bytes 4'b0010: 64 bytes In general, the presence of the BurstMin parameter makes the BurstShort parameter obsolete.
burst_min_in	4	Input	Encodes the BurstMin parameter for the IP core. The IP core supports the following valid values for this signal: <ul style="list-style-type: none"> 4'b0000: Disable optional enhanced scheduling. Intel recommends you do not drive this value in variations in dual segment mode. If you disable enhanced scheduling, performance is non-optimal. 4'b0001: 32 bytes 4'b0010: 64 bytes 4'b0100: 128 bytes The BurstMin parameter should have a value that is less than or equal to half of the value of the BurstMax parameter. Intel recommends that you modify the value of this input signal only when no traffic is present on the TX user data interface. You do not need to reset the IP core.

Table 25. ECC Status Signals

Signal Name	Width (Bits)	I/O Direction	Description
itx_eccstatus	2	Output	Indicates the TX ECC status.

continued...

⁴ Synchronous with `rx_usr_clk`.



Signal Name	Width (Bits)	I/O Direction	Description
			<ul style="list-style-type: none"> Bit 1: Correctable error status Bit 0: Uncorrectable error status
irx_eccstatus	2	Output	Indicates the RX ECC status. <ul style="list-style-type: none"> Bit 1: Correctable error status Bit 0: Uncorrectable error status

5.7 External PLL Interface Signals

Table 26. ATX PLL Interface Signals

Signal Name	Width (Bits)	I/O Direction	Description
tx_pll_locked	1	Input	PLL-locked indication from external TX PLL.
tx_pll_cal_busy	1	Input	PLL-busy indication from external TX PLL.
tx_serial_clk	NUM_LANES	Input	High-speed clock for Stratix 10 transceiver channel, provided from external TX PLL.
tx_pll_powerdown	1	Output	Output signal from the IP core internal reset controller. The IP core asserts this signal to tell the external PLLs to power down.

Related Links

- [Stratix 10 L-Tile Transceiver PHY User Guide](#)
 For more details about the L-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.
- [Stratix 10 H-Tile Transceiver PHY User Guide](#)
 For more details about the H-tile transceiver reset and dynamic reconfiguration of transceiver channels and PLLs.



6 Register Map

The Interlaken IP core control registers are 32 bits wide and are accessible to you using the management interface, an Avalon-MM interface which conforms to the *Avalon Interface Specifications*. This table lists the registers available in the IP core. All unlisted locations are reserved.

Table 27. IP Core Register Map

Offset	Name	R/W	Description
8'h0	PCS_BASE	RO	[31:8] – Constant "HSI" ASCII [7:0] – version number Despite its name, this register does not encode the hard PCS base address.
8'h1	LANE_COUNT	RO	Number of lanes
8'h3	ELAPSED_SEC	RO	[23:0] - Elapsed seconds since power up. The IP core calculates this value from the management interface clock (<code>mm_clk</code>) for diagnostic purposes. During continuous operation, this value rolls over every 194 days.
8'h4	TX_EMPTY	RO	[NUM_LANES-1:0] – Transmit FIFO status (empty)
8'h5	TX_FULLL	RO	[NUM_LANES-1:0] – Transmit FIFO status (full)
8'h6	TX_PEMPTY	RO	[NUM_LANES-1:0] – Transmit FIFO status (partially empty)
8'h7	TX_PFULL	RO	[NUM_LANES-1:0] – Transmit FIFO status (partially full)
8'h8	RX_EMPTY	RO	[NUM_LANES-1:0] – Receive FIFO status (empty)
8'h9	RX_FULLL	RO	[NUM_LANES-1:0] – Receive FIFO status (full)
8'hA	RX_PEMPTY	RO	[NUM_LANES-1:0] – Receive FIFO status (partially empty)
8'hB	RX_PFULL	RO	[NUM_LANES-1:0] – Receive FIFO status (partially full)
8'hD	RX_KHZ	RO	RX recovered clock frequency (kHz) If you turn off Include diagnostic features , this register is not available.
8'hE	TX_KHZ	RO	TX serial clock frequency (kHz) If you turn off Include diagnostic features , this register is not available.
8'h10	PLL_LOCKED	RO	Bit[0] – Transmit PLL lock indication. One lock indicator per transceiver block. Bits that correspond to unused transceiver block PLLs are forced to 1.
8'h11	FREQ_LOCKED	RO	[NUM_LANES-1:0] – Clock data recovery is frequency locked on the inbound data stream
8'h12	LOOPBACK	RW	[NUM_LANES-1:0] – For each lane, write a 1 to activate internal TX to RX serial loopback mode, or write a 0 to disable the loopback for normal operation.

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Offset	Name	R/W	Description
8'h13	RESET	RW	<p>Bit 9 : 1 = Force lock to data mode Bit 8 : 1 = Force lock to reference mode Bit 7 : 1 = Synchronously clear the TX-side error counters and sticky flags Bit 6 : 1 = Synchronously clear the RX-side error counters and sticky flags</p> <p>The normal operating state for this register is all zeros, to allow automatic reset control. These bits are intended primarily for hardware debugging use. Bit 2 is a good general purpose soft reset. Bits 6 and 7 are convenient for monitoring long stretches of error-free operation.</p>
8'h20	ALIGN	RO	<p>Bit 0 : TX lanes are aligned Bit 1 : RX lanes are aligned.</p>
8'h21	WORD_LOCK	RO	[NUM_LANES-1:0] – Word (block) boundaries have been identified in the RX stream.
8'h22	SYNC_LOCK	RO	[NUM_LANES-1:0] – Metaframe synchronization has been achieved.
8'h23	CRC0	RO	<p>4 bit counters indicating CRC errors in lanes 7,6,5,4,3,2,1,0. These will saturate at F, and you clear them by setting bit 6 in the RESET register. If you turn off Include diagnostic features, this register is not available.</p>
8'h24	CRC1	RO	<p>4 bit counters indicating CRC errors in lanes [15:8]. These will saturate at F, and you clear them by setting bit 6 in the RESET register. If you turn off Include diagnostic features, this register is not available.</p>
8'h25	CRC2	RO	<p>4 bit counters indicating CRC errors in lanes [23:16]. These will saturate at F, and you clear them by setting bit 6 in the RESET register. If you turn off Include diagnostic features, this register is not available.</p>
8'h25	CRC3	RO	<p>4 bit counters indicating CRC errors in lanes [31:24]. These will saturate at F, and you clear them by setting bit 6 in the RESET register. If you turn off Include diagnostic features, this register is not available.</p>
8'h28	RX_LOA	RO	Bit [0] – Sticky flag indicating loss of RX side lane-to-lane alignment since this bit was last cleared through the RESET register. Typically, the IP core asserts this bit in case of a catastrophic problem such as one or more lanes going down.
8'h29	TX_LOA	RO	Bit [0] – Sticky flag indicating loss of TX side lane to lane alignment since this bit was last cleared through the RESET register. Typically, the IP core asserts this bit in case of a TX FIFO underflow / overflow caused by a significant deviation from the expected data flow rate through the TX PCS.
8'h38	CRC32_ERR_INJECT	RW	<p>[NUM_LANES-1:0] - When a bit has the value of 1, the IP core injects CRC32 errors on the corresponding TX lane. When it has the value of 0, the IP core does not inject errors on the TX lane. You must maintain each bit at the value of 1 for the duration of a Meta Frame, at least, to ensure that the IP core transmits at least one CRC32 error. If you turn off Include diagnostic features, this register is not available.</p>

Related Links

[Avalon Interface Specifications](#)



7 Test Features

Depending on the features you turn on in the IP parameter editor, your Interlaken IP core supports the following test features:

7.1 Internal Serial Loopback Mode

The Interlaken IP core supports an internal TX to RX serial loopback mode.

To turn on internal serial loopback:

- Reset the IP core by asserting and then deasserting the active low `reset_n` signal.
- After reset completes, set the value of bits [NUM_LANES-1:0] of the `LOOPBACK` register at offset 0x12 to all ones.
Note: Refer to "IP Core Reset" for information about the required wait period for register access.
- Monitor the RX lanes aligned bit (bit 0) of the `ALIGN` register at offset 0x20 or the `rx_lanes_aligned` output signal. After the RX lanes are aligned, the IP core is in internal serial loopback mode.

Resetting the IP core turns off internal serial loopback. To turn off internal serial loopback:

- Reset the IP core by asserting and then deasserting the active low `reset_n` signal. Resetting the IP core sets the value of bits [NUM_LANES-1:0] of the `LOOPBACK` register at offset 0x12 to all zeros.
- Monitor the RX lanes aligned bit (bit 0) of the `ALIGN` register at offset 0x20 or the `rx_lanes_aligned` output signal. After the RX lanes are aligned, the IP core is in normal operational mode.

Related Links

[IP Core Reset](#) on page 31

7.2 External Loopback Mode

The Interlaken IP core operates correctly in an external loopback configuration.

To put the IP core in external loopback mode, connect the TX lanes to the RX lanes of the IP core. This mode does not require any special programming of the IP core.



A Document Revision History

Date	Version	Changes
May 2017	2017.05.08	<ul style="list-style-type: none"> • Updated the resource utilization in <i>Table: FPGA Resource Utilization</i>. • Added the new supported combinations of number of lanes and data rate (6x25.3G and 12x25.3G) in <i>Table: IP Core Supported Combinations of Number of Lanes and Data Rate</i> • Corrected the steps for <i>Specifying the IP Core Parameters and Options</i>. • Added the transceiver reference clock frequency for 25.3 Gbps data rate in the <i>Table: Interlaken IP Core Parameter Settings</i> and <i>Table: Clock and Reset Interface Signals</i>.
December 2016	2016.12.19	<ul style="list-style-type: none"> • Dynamic reconfiguration support is now available for Stratix 10 devices. • Added a new parameter <code>VCCR_GXB</code> and <code>VCCT_GXB</code> supply voltage for the transceivers in the table: <i>Interlaken IP Core Parameter Settings</i>.
August 2016	2016.08.08	Initial version for Quartus Prime Pro – Stratix 10 Edition Beta software.

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