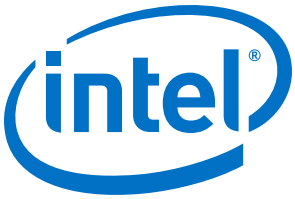

High-Definition Multimedia Interface (HDMI) IP Core User Guide

UG-HDMI
2017.05.08

Last updated for Intel® Quartus® Prime Design Suite: 17.0


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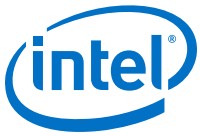


1 HDMI Quick Reference

The High-Definition Multimedia Interface (HDMI) IP core provides support for next-generation video display interface technology.

Information		Description
Release Information	Version	17.0
	Release	May 2017
	Ordering Code	IP-HDMI
IP Core Information	Core Features	• Conforms to the *High-Definition Multimedia Interface (HDMI) specification versions 1.4 and 2.0* • Supports transmitter and receiver on a single device transceiver quad • Supports pixel frequency up to 600 MHz • Supports RGB and YCbCr 444, 422, and 420 color modes • Accepts standard H-SYNC, V-SYNC, data enable, RGB video format, and YCbCr video format • Supports 2-channel and 8-channel audios • Supports 1, 2, or 4 symbols per clock • Supports 8, 10, 12, or 16 bits per color (bpc) • Supports Digital Visual Interface (DVI)
	Typical Application	• Interfaces within a PC and monitor • External display connections, including interfaces between a PC and monitor or projector, between a PC and TV, or between a device such as a DVD player and TV display
	Device Family	Supports Intel Arria® 10, Arria V, and Stratix® V FPGA devices
	Design Tools	• Intel Quartus® Prime software for IP design instantiation and compilation • TimeQuest Timing Analyzer in the Quartus Prime software for timing analysis • ModelSim* - Intel FPGA Edition or ModelSim software for design simulation

Related Links

- HDMI IP Core Design Example User Guide
  For more information about the Arria 10 HDMI design example.
- HDMI IP Core User Guide Archives on page 76
  Provides a list of user guides for previous versions of the HDMI IP core.

2 HDMI Overview

The High-Definition Multimedia Interface (HDMI) IP core provides support for next generation video display interface technology.

The HDMI standard specifies a digital communications interface for use in both internal and external connections:

- Internal connections—interface within a PC and monitor
- External display connections—interface between a PC and monitor or projector, between a PC and TV, or between a device such a DVD player and TV display.

The HDMI system architecture consists of sinks and sources. A device may have one or more HDMI inputs and outputs.

The HDMI cable and connectors carry four differential pairs that make up the Transition Minimized Differential Signaling (TMDS) data and clock channels. You can use these channels to carry video, audio, and auxiliary data.

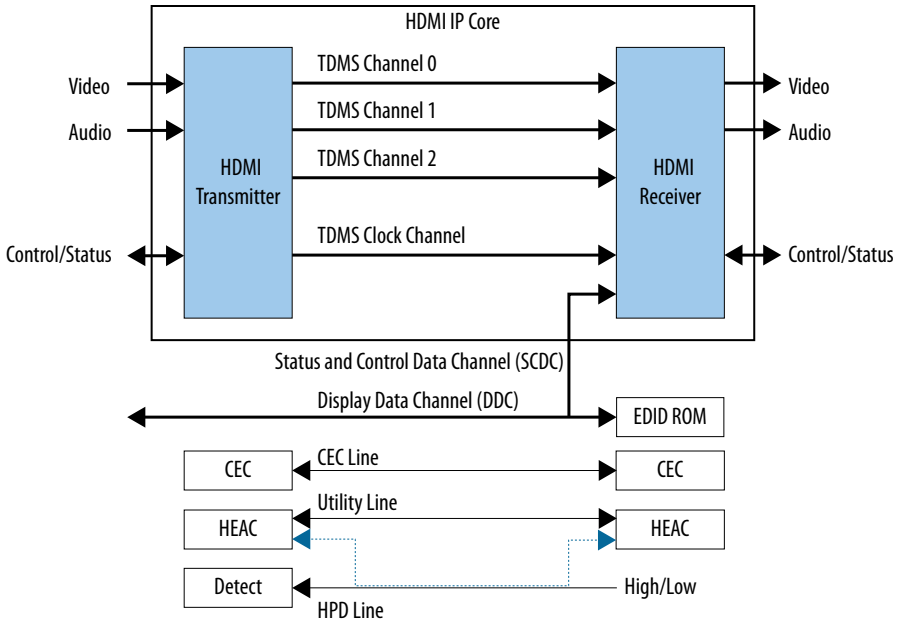
The HDMI also carries a Video Electronics Standards Association (VESA) Display Data Channel (DDC) and Status and Control Data Channel (SCDC). The DDC configures and exchanges status between a single source and a single sink. The source uses the DDC to read the sink's Enhanced Extended Display Identification Data (E-EDID) to discover the sink's configuration and capabilities. The SCDC supports the sink's read requests.

The optional Consumer Electronics Control (CEC) protocol provides high-level control functions between various audio visual products in your environment.

The optional HDMI Ethernet and Audio Return Channel (HEAC) provides Ethernet compatible data networking between connected devices and an audio return channel in the opposite direction of TMDS. The HEAC also uses Hot-Plug Detect (HPD) line for signal transmission.

Figure 1. HDMI IP Core Block Diagram

The figure below illustrates the blocks in the HDMI IP core.



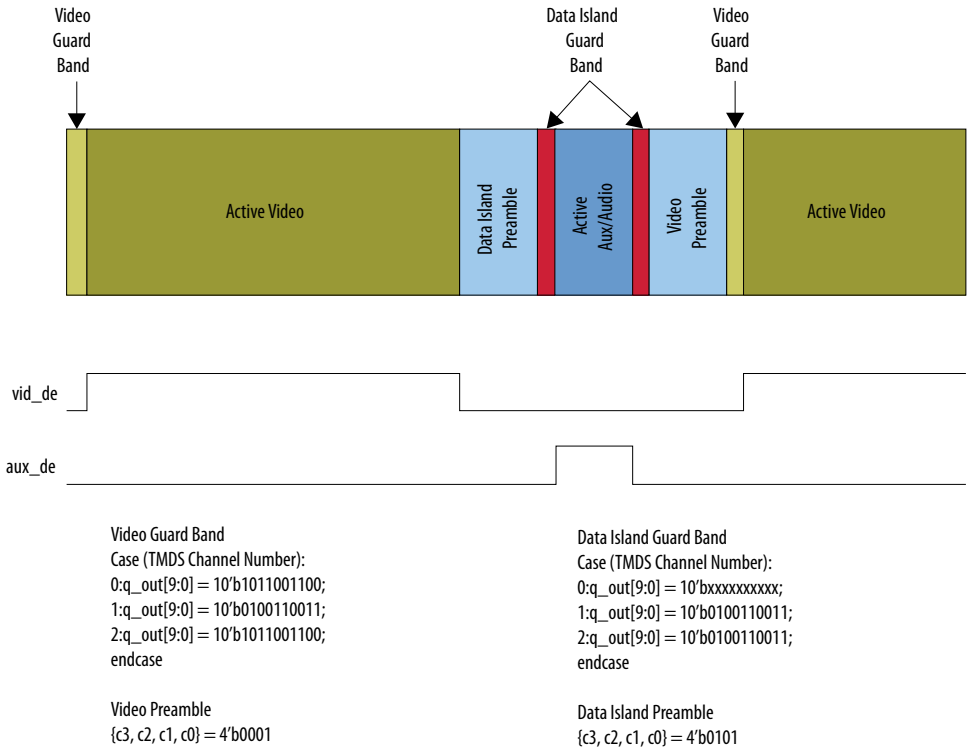
Based on TMDS encoding, the HDMI protocol allows the transmission of both audio and video data between source and sink devices.

An HDMI interface consists of three color channels accompanied by a single clock channel. You can use each color line to transfer both individual RGB colors and auxiliary data.

The receiver uses the TMDS clock as a frequency reference for data recovery on the three TMDS data channels. This clock typically runs at the video pixel rate.

TMDS encoding is based on an 8-bit to 10-bit algorithm. This protocol attempts to minimize data channel transmission and yet maintain sufficient bandwidth so that a sink device can lock reliably to the data stream.

Figure 2. HDMI Video Stream Data



The figure above illustrates two data streams:

- Data stream in green—transports color data
- Data stream in dark blue—transports auxiliary data

Table 1. Video Data and Auxiliary Data

The table below describes the function of the video data and auxiliary data.

Data	Description
Video data	• Packed representation of the video pixels clocked at the source pixel clock. • Encoded using the TMDS 8-bit to 10-bit algorithm.
Auxiliary data	• Transfers audio data together with a range of auxiliary data packets. • Sink devices use auxiliary data packets to correctly reconstruct video and audio data. • Encoded using the TMDS Error Reduction Coding–4 bits (TERC4) encoding algorithm.

Each data stream section is preceded with guard bands and pre-ambles. The guard bands and pre-ambles allow for accurate synchronization with received data streams.

The following figures show the arrangement of the video data, video data enable, video H-SYNC, and video V-SYNC in 1, 2, and 4 symbols per clock.

Figure 3. Video Data, Video Data Valid, H-SYNC, and V-SYNC—1 Symbol per Clock

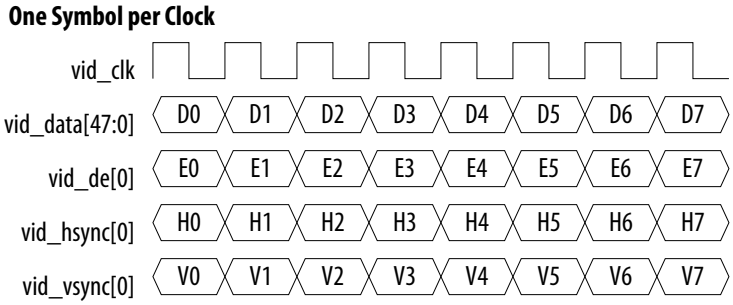


Figure 4. Video Data, Video Data Valid, H-SYNC, and V-SYNC—2 Symbols per Clock

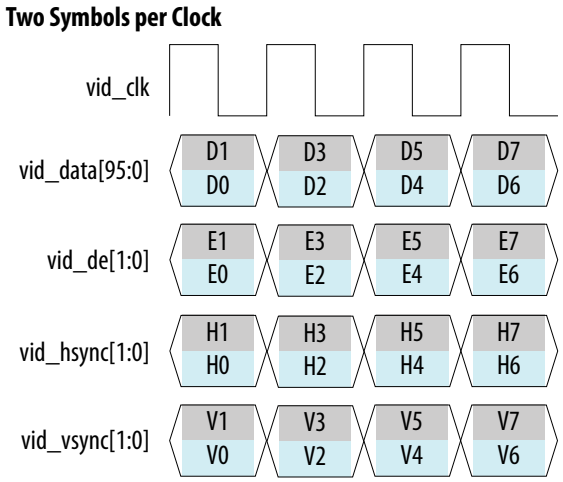
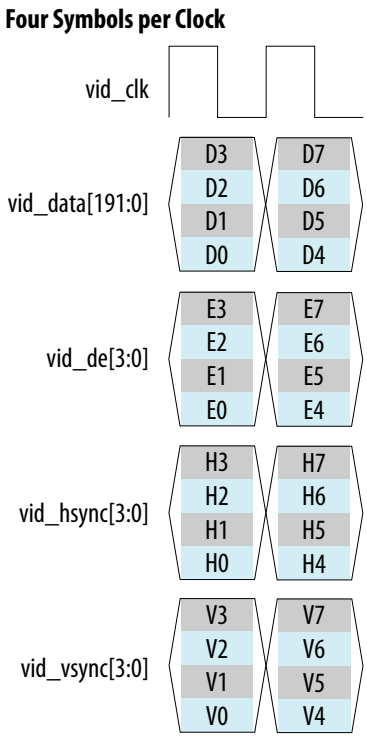


Figure 5. Video Data, Video Data Valid, H-SYNC, and V-SYNC—4 Symbols per Clock



2.1 Resource Utilization

The resource utilization data indicates typical expected performance for the HDMI IP core device.

Table 2. HDMI Data Rate

The table lists the maximum data rates for HDMI core configurations of 1, 2, and 4 symbols per clock.

Devices	Maximum Data Rate (Mbps)		
	1 Symbol per Clock	2 Symbols per Clock	4 Symbols per Clock
Arria 10	Not Supported	5,940 (Example: 4Kp60 8bpc)	Not Supported
Arria V GX	1,875 (Example: 1080p60 10bpc)	3,276.8 (Example: 4Kp30 8bpc)	5,940 (Example: 4Kp60 8bpc)
Stratix V	5,800 (Example: 4Kp30 12bpc)	5,940 (Example: 4Kp60 8bpc)	Not Supported

Table 3. Color Depth Supported for Each Video Format

Video Format	Color Depth			
	8	10	12	16
RGB	Yes	Yes	Yes	Yes
YCbCr 4:4:4	Yes	Yes	Yes	Yes
YCbCr 4:2:2[1]	Not applicable	Not applicable	Yes	Not applicable
YCbCr 4:2:0	Yes	Yes	Yes	Yes

Table 4. HDMI Resource Utilization

The table lists the performance data for the HDMI IP core targeting Arria 10, Arria V GX, and Stratix V devices.

Device	Symbols per Clock	Direction	ALMs	Logic Registers		Memory	
				Primary	Secondary	Bits	M10K or M20K
Arria 10	2	RX	3,359	4,276	795	38,400	14
	2	TX	3,374	5,014	1,543	12,680	13
Arria V GX	1	RX	2,630	4,039	402	35,712	13
	1	TX	2,700	4,462	417	11,108	11
	2	RX	3,446	4,656	531	38,400	14
	2	TX	3,759	6,091	450	12,680	13
	4	RX	4,895	5,937	614	43,776	20
	4	TX	6,135	9,156	445	15,824	18
Stratix V	1	RX	2,592	3,946	398	35,712	13
	1	TX	2,634	4,415	461	11,108	11
	2	RX	3,337	4,619	440	38,400	14
	2	TX	3,644	5,919	680	12,680	13

Table 5. Recommended Speed Grades for Arria 10 Devices

Device	Lane Rate (Mbps)	Interface Width (bits)	Speed Grades
Arria 10	6,000	20	-1, -2

1 According to section 6.5.1 of the HDMI 1.4b specifications, 8 and 10 bits per color use the same pixel encoding as 12 bits per color, but the valid bits are left-justified with zeroes padding the bits below the least significant bit.

3 HDMI Getting Started

This chapter provides a general overview of the Intel IP core design flow to help you quickly get started with the HDMI IP core. The Intel FPGA IP Library is installed as part of the Quartus Prime installation process. You can select and parameterize any Intel FPGA IP core from the library. Intel provides an integrated parameter editor that allows you to customize the HDMI IP core to support a wide variety of applications. The parameter editor guides you through the setting of parameter values and selection of optional ports.

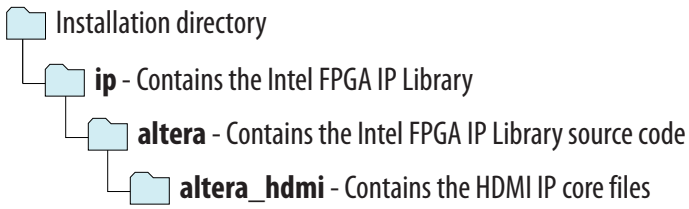
Related Links

- 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.

3.1 Installing and Licensing IP Cores

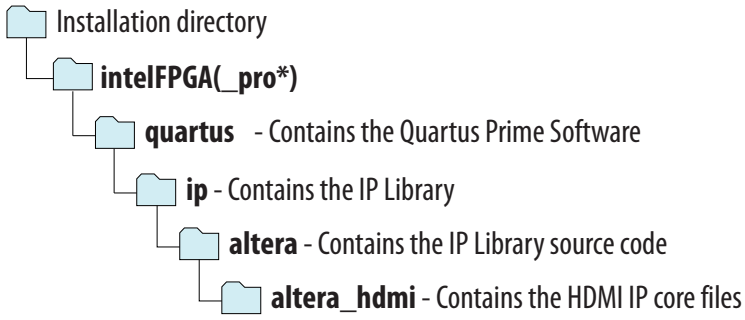
The Quartus Prime software includes the Intel FPGA IP Library. The library provides many useful IP core functions for production use without additional license. You can fully evaluate any licensed Intel FPGA IP core in simulation and in hardware until you are satisfied with its functionality and performance. The HDMI IP core is part of the Intel FPGA IP Library, which is distributed with the Quartus Prime software and downloadable from www.altera.com.

Figure 6. HDMI Installation Path



Note: The default IP installation directory on Windows* is `<drive>:\altera\<version number>`; on Linux* it is `<home directory>/altera/ <version number>`.

Figure 7. HDMI Installation Path



Note: The default IP installation directory on Windows is *<drive>*:\intelFPGA_pro\quartus\ip\altera; on Linux it is *<home directory>*/intelFPGA_pro/quartus/ip/altera.

After you purchase a license for the HDMI IP core, you can request a license file from the licensing site and install it on your computer. When you request a license file, Intel emails you a license.dat file. If you do not have Internet access, contact your local Intel representative.

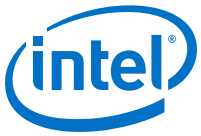
Related Links

- Intel FPGA Licensing Website
- Intel FPGA Software Installation and Licensing Manual

3.2 Specifying IP Core Parameters and Options

Follow these steps to specify the HDMI IP core parameters and options.

1. Create a Quartus Prime project using the **New Project Wizard** available from the File menu.
2. On the **Tools** menu, click **IP Catalog**.
3. Under **Installed IP**, double-click **Library ➤ Interface ➤ Protocols ➤ Audio&Video ➤ HDMI**.
   The parameter editor appears.
4. Specify a top-level name for your custom IP variation. This name identifies the IP core variation files in your project. If prompted, also specify the targeted FPGA device family and output file HDL preference. Click **OK**.
5. Specify parameters and options in the HDMI parameter editor:
   - Optionally select preset parameter values. Presets specify all initial parameter values for specific applications (where provided).
   - Specify parameters defining the IP core functionality, port configurations, and device-specific features.
   - Specify options for generation of a timing netlist, simulation model, testbench, or example design (where applicable).
   - Specify options for processing the IP core files in other EDA tools.
6. Click **Generate** to generate the IP core and supporting files, including simulation models.



7. Click **Close** when file generation completes.
8. Click **Finish**.
9. If you generate the HDMI IP core instance in a Quartus Prime project, you are prompted to add `Quartus Prime IP File (.qip)` and `Quartus Prime Simulation IP File (.sip)` to the current Quartus Prime project.

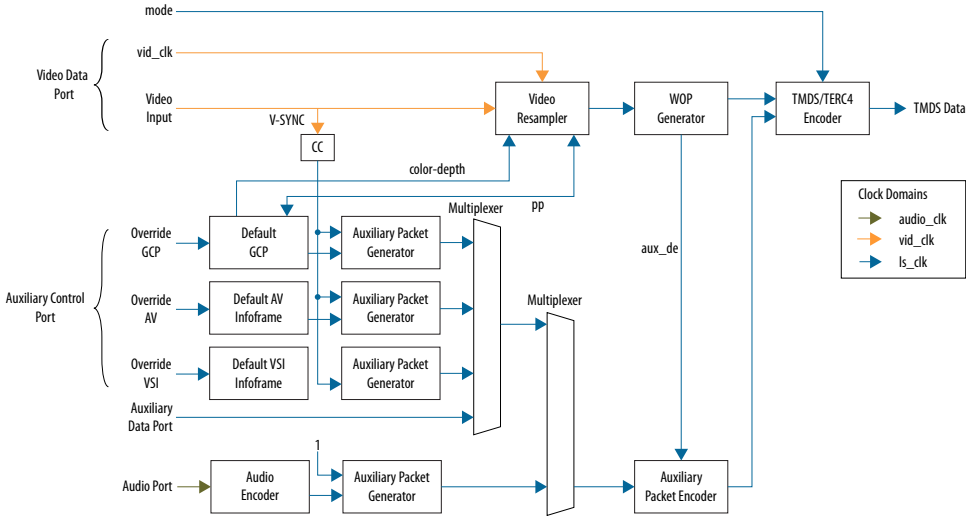
4 HDMI Source

4.1 Source Functional Description

The HDMI source core provides direct connection to the Transceiver Native PHY through a 10-bit, 20-bit, or 40-bit parallel data path.

Figure 8. HDMI Source Signal Flow Diagram

The figure below shows the flow of the HDMI source signals. The figure shows the various clocking domains used within the core.



The source core provides four 10-bit, 20-bit or 40-bit parallel data paths corresponding to the 3 color channels and the clock channel.

The source core accepts video, audio, and auxiliary channel data streams. The core produces a TMDS/TERC4 encoded data stream that would typically connect to the high-speed transceiver parallel data inputs.

Central to the core is the TMDS/TERC4 encoder. The encoder processes either video or auxiliary data.

4.1.1 Source TMDS/TERC4 Encoder

The source TMDS/TERC4 encoder implements 8-bit to 10-bit and 4-bit to 10-bit algorithms as defined in the *HDMI Specification Ver.2.0*. Each channel has its own encoder.

The encoder processes symbol data at 1, 2, or 4 symbols per clock.

When the encoder operates in 2 or 4 symbols per clock, it also produces the output in the form of two or four encoded symbols per clock.

The TMDS/TERC4 encoder also produces digital visual interface (DVI) signaling when you deassert the mode input signal. DVI signaling is identical to HDMI signaling, except for the absence of data and video islands and TERC4 auxiliary data.

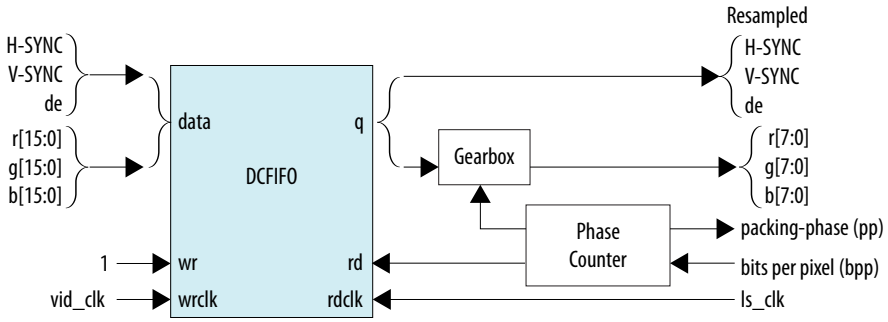
4.1.2 Source Video Resampler

The core resamples the video data based on the current color depth.

The video resampler consists of a gearbox and a dual-clock FIFO (DCFIFO).

Figure 9. Source Video Resampler Signal Flow Diagram

The figure below shows the components of the video resampler and the signal flow between these components.



The resampler adheres to the recommended phase encoding method described in *HDMI Specification Ver.1.4b*.

- The phase counter must register the last packing-phase (pp) of the last pixel of the last active line.
- The resampler then transmits the pp value to the attached sink device in the General Control Packet (GCP) for packing synchronization.

Figure 10. RGB 4:4:4 Mapped to the Respective TMDS Channels

The R, G, and B components of the first pixel for a given line of video are transferred on the first pixel of the video data period following the Guard Band characters.

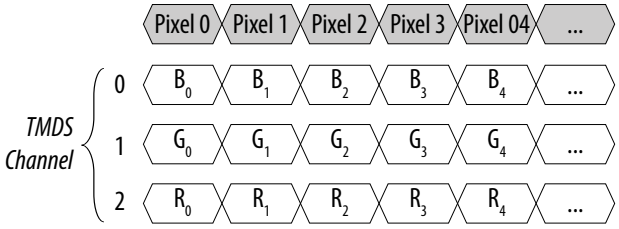


Figure 11. YCbCr 4:4:4 Mapped to the Respective TMDS Channels

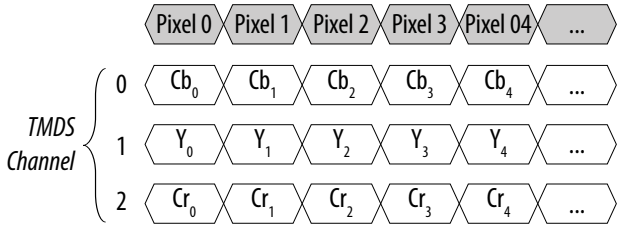


Figure 12. Source Pixel Data Input Format RGB/YCbCr 4:4:4

The figure below shows the RGB color space pixel bit-field mappings.

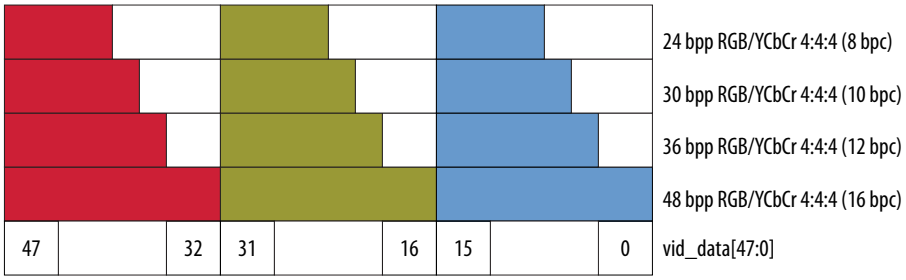
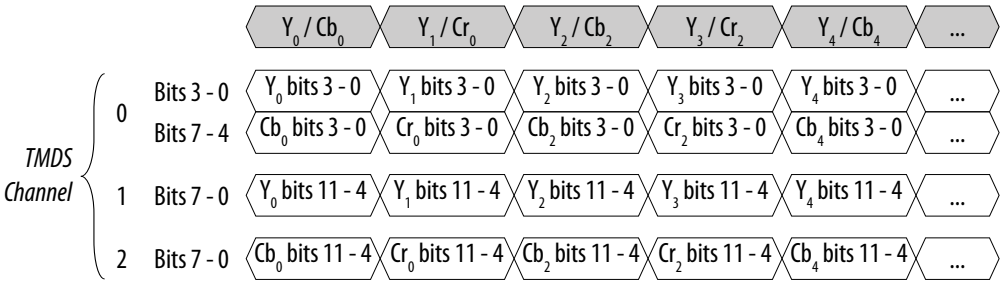


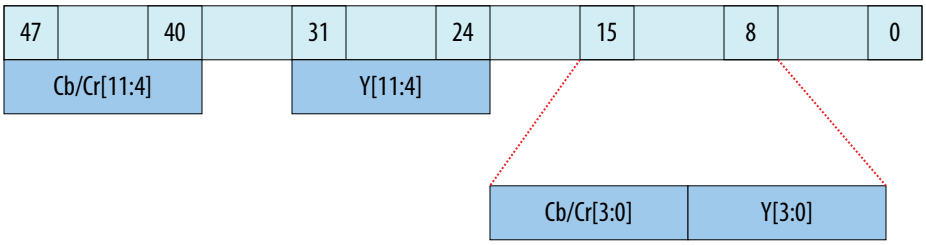
Figure 13. YCbCr 4:2:2 Mapped to the Respective TMDS Channels



The higher order 8 bits of the Y samples are mapped to the 8 bits of Channel 1 and the lower order 4 bits are mapped to the lower order 4 bits of Channel 0.

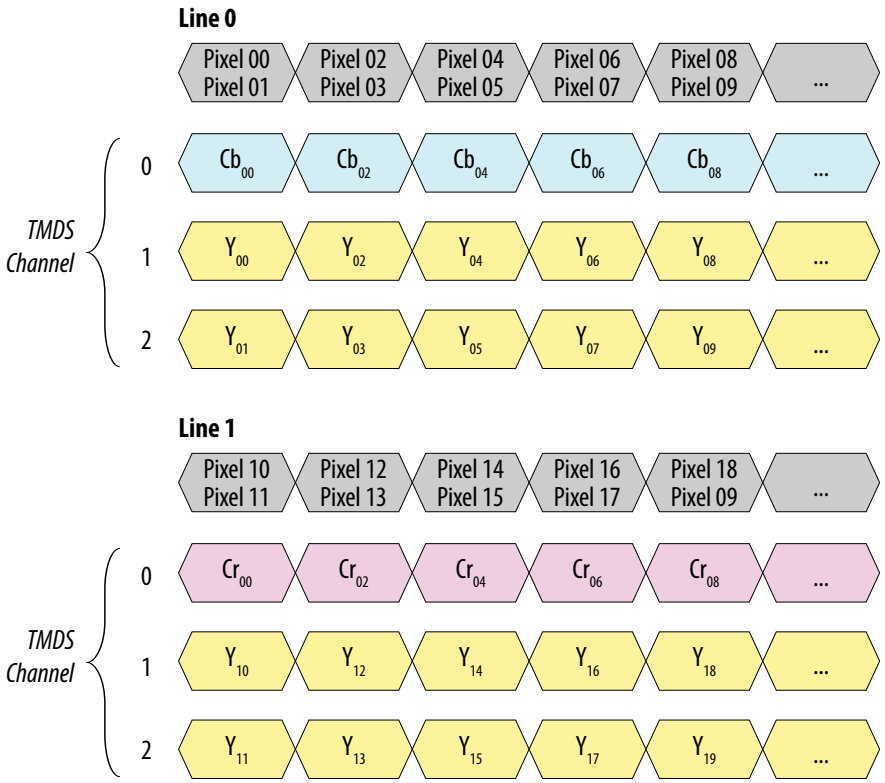
The first pixel transmitted within a Video Data Period contains three components, Y0, Cb0 and Cr0. The Y0 and Cb0 components are transmitted during the first pixel period while Cr0 is transmitted during the second pixel period. This second pixel period also contains the only component for the second pixel, Y1. In this way, the link carries one Cb sample for every two pixels and one Cr sample for every two pixels. These two components (Cb and Cr) are multiplexed onto the same signal paths on the link.

Figure 14. Source Pixel Data Input Format YCbCr 4:2:2—12 bpc



The 4:2:2 data requires only two components per pixel. Therefore, each component is allocated more bits. The available 24 bits are split into 12 bits for the Y component and 12 bits for C components.

Figure 15. YCbCr 4:2:0 Mapped to the Respective TMDS Channels



The two horizontally successive 8-bit Y components are transmitted in TMDS Channels 1 and 2, in that order. The 8-bit Cb or Cr components are transmitted alternately in TMDS Channel 0, line by line.

4.1.2.1 Mapping Formats

The following figures illustrate the mapping of different formats.

Figure 16. Mapping Two 8-Bit per Component YCbCr 4:2:0 to One 24-Bit YCbCr 4:4:4 Pixel (Pre Deep Color Packing)

			First 8 YCbCr 4:2:0 Pixels on Each Line			
		Equivalent YCbCr 4:4:4 Pixel	**YCbCr 4:2:0 Pixel 0/1**	**YCbCr 4:2:0 Pixel 2/3**	**YCbCr 4:2:0 Pixel 4/5**	**YCbCr 4:2:0 Pixel 6/7**
Line 0	Channel 0	Cb[7:0]	Cb_{00}[7:0]	Cb_{02}[7:0]	Cb_{04}[7:0]	Cb_{06}[7:0]
	Channel 1	Y[7:0]	Y_{00}[7:0]	Y_{02}[7:0]	Y_{04}[7:0]	Y_{06}[7:0]
	Channel 2	Cr[7:0]	Y_{01}[7:0]	Y_{03}[7:0]	Y_{05}[7:0]	Y_{07}[7:0]
Line 1	Channel 0	Cb[7:0]	Cr_{00}[7:0]	Cr_{02}[7:0]	Cr_{04}[7:0]	Cr_{06}[7:0]
	Channel 1	Y[7:0]	Y_{10}[7:0]	Y_{12}[7:0]	Y_{14}[7:0]	Y_{16}[7:0]
	Channel 2	Cr[7:0]	Y_{11}[7:0]	Y_{13}[7:0]	Y_{15}[7:0]	Y_{17}[7:0]
Line 2	Channel 0	Cb[7:0]	Cb_{20}[7:0]	Cb_{22}[7:0]	Cb_{24}[7:0]	Cb_{26}[7:0]
	Channel 1	Y[7:0]	Y_{20}[7:0]	Y_{22}[7:0]	Y_{24}[7:0]	Y_{26}[7:0]
	Channel 2	Cr[7:0]	Y_{21}[7:0]	Y_{23}[7:0]	Y_{25}[7:0]	Y_{27}[7:0]
Line 3	Channel 0	Cb[7:0]	Cr_{20}[7:0]	Cr_{22}[7:0]	Cr_{24}[7:0]	Cr_{26}[7:0]
	Channel 1	Y[7:0]	Y_{30}[7:0]	Y_{32}[7:0]	Y_{34}[7:0]	Y_{36}[7:0]
	Channel 2	Cr[7:0]	Y_{31}[7:0]	Y_{33}[7:0]	Y_{35}[7:0]	Y_{37}[7:0]

Figure 17. Mapping Two 10-Bit per Component YCbCr 4:2:0 to One 30-Bit YCbCr 4:4:4 Pixel (Pre Deep Color Packing)

			First 10 YCbCr 4:2:0 Pixels on Each Line			
		Equivalent YCbCr 4:4:4 Pixel	**YCbCr 4:2:0 Pixel 0/1**	**YCbCr 4:2:0 Pixel 2/3**	**YCbCr 4:2:0 Pixel 4/5**	**YCbCr 4:2:0 Pixel 6/7**
Line 0	Channel 0	Cb[9:0]	Cb_{00}[9:0]	Cb_{02}[9:0]	Cb_{04}[9:0]	Cb_{06}[9:0]
	Channel 1	Y[9:0]	Y_{00}[9:0]	Y_{02}[9:0]	Y_{04}[9:0]	Y_{06}[9:0]
	Channel 2	Cr[9:0]	Y_{01}[9:0]	Y_{03}[9:0]	Y_{05}[9:0]	Y_{07}[9:0]
Line 1	Channel 0	Cb[9:0]	Cr_{00}[9:0]	Cr_{02}[9:0]	Cr_{04}[9:0]	Cr_{06}[9:0]
	Channel 1	Y[9:0]	Y_{10}[9:0]	Y_{12}[9:0]	Y_{14}[9:0]	Y_{16}[9:0]
	Channel 2	Cr[9:0]	Y_{11}[9:0]	Y_{13}[9:0]	Y_{15}[9:0]	Y_{17}[9:0]
Line 2	Channel 0	Cb[9:0]	Cb_{20}[9:0]	Cb_{22}[9:0]	Cb_{24}[9:0]	Cb_{26}[9:0]
	Channel 1	Y[9:0]	Y_{20}[9:0]	Y_{22}[9:0]	Y_{24}[9:0]	Y_{26}[9:0]
	Channel 2	Cr[9:0]	Y_{21}[9:0]	Y_{23}[9:0]	Y_{25}[9:0]	Y_{27}[9:0]
Line 3	Channel 0	Cb[9:0]	Cr_{20}[9:0]	Cr_{22}[9:0]	Cr_{24}[9:0]	Cr_{26}[9:0]
	Channel 1	Y[9:0]	Y_{30}[9:0]	Y_{32}[9:0]	Y_{34}[9:0]	Y_{36}[9:0]
	Channel 2	Cr[9:0]	Y_{31}[9:0]	Y_{33}[9:0]	Y_{35}[9:0]	Y_{37}[9:0]

Figure 18. Mapping Two 12-Bit per Component YCbCr 4:2:0 to One 36-Bit YCbCr 4:4:4 Pixel (Pre Deep Color Packing)

First 12 YCbCr 4:2:0 Pixels on Each Line

		Equivalent YCbCr 4:4:4 Pixel	YCbCr 4:2:0 Pixel 0/1	YCbCr 4:2:0 Pixel 2/3	YCbCr 4:2:0 Pixel 4/5	YCbCr 4:2:0 Pixel 6/7
Line 0	Channel 0	Cb[11:0]	Cb_{00}[11:0]	Cb_{02}[11:0]	Cb_{04}[11:0]	Cb_{06}[11:0]
	Channel 1	Y[11:0]	Y_{00}[11:0]	Y_{02}[11:0]	Y_{04}[11:0]	Y_{06}[11:0]
	Channel 2	Cr[11:0]	Y_{01}[11:0]	Y_{03}[11:0]	Y_{05}[11:0]	Y_{07}[11:0]
Line 1	Channel 0	Cb[11:0]	Cr_{00}[11:0]	Cr_{02}[11:0]	Cr_{04}[11:0]	Cr_{06}[11:0]
	Channel 1	Y[11:0]	Y_{10}[11:0]	Y_{12}[11:0]	Y_{14}[11:0]	Y_{16}[11:0]
	Channel 2	Cr[11:0]	Y_{11}[11:0]	Y_{13}[11:0]	Y_{15}[11:0]	Y_{17}[11:0]
Line 2	Channel 0	Cb[11:0]	Cb_{20}[11:0]	Cb_{22}[11:0]	Cb_{24}[11:0]	Cb_{26}[11:0]
	Channel 1	Y[11:0]	Y_{20}[11:0]	Y_{22}[11:0]	Y_{24}[11:0]	Y_{26}[11:0]
	Channel 2	Cr[11:0]	Y_{21}[11:0]	Y_{23}[11:0]	Y_{25}[11:0]	Y_{27}[11:0]
Line 3	Channel 0	Cb[11:0]	Cr_{20}[11:0]	Cr_{22}[11:0]	Cr_{24}[11:0]	Cr_{26}[11:0]
	Channel 1	Y[11:0]	Y_{30}[11:0]	Y_{32}[11:0]	Y_{34}[11:0]	Y_{36}[11:0]
	Channel 2	Cr[11:0]	Y_{31}[11:0]	Y_{33}[11:0]	Y_{35}[11:0]	Y_{37}[11:0]

Figure 19. Mapping Two 16-Bit per Component YCbCr 4:2:0 to One 48-Bit YCbCr 4:4:4 Pixel (Pre Deep Color Packing)

First 16 YCbCr 4:2:0 Pixels on Each Line

		Equivalent YCbCr 4:4:4 Pixel	YCbCr 4:2:0 Pixel 0/1	YCbCr 4:2:0 Pixel 2/3	YCbCr 4:2:0 Pixel 4/5	YCbCr 4:2:0 Pixel 6/7
Line 0	Channel 0	Cb[15:0]	Cb_{00}[15:0]	Cb_{02}[15:0]	Cb_{04}[15:0]	Cb_{06}[15:0]
	Channel 1	Y[15:0]	Y_{00}[15:0]	Y_{02}[15:0]	Y_{04}[15:0]	Y_{06}[15:0]
	Channel 2	Cr[15:0]	Y_{01}[15:0]	Y_{03}[15:0]	Y_{05}[15:0]	Y_{07}[15:0]
Line 1	Channel 0	Cb[15:0]	Cr_{00}[15:0]	Cr_{02}[15:0]	Cr_{04}[15:0]	Cr_{06}[15:0]
	Channel 1	Y[15:0]	Y_{10}[15:0]	Y_{12}[15:0]	Y_{14}[15:0]	Y_{16}[15:0]
	Channel 2	Cr[15:0]	Y_{11}[15:0]	Y_{13}[15:0]	Y_{15}[15:0]	Y_{17}[15:0]
Line 2	Channel 0	Cb[15:0]	Cb_{20}[15:0]	Cb_{22}[15:0]	Cb_{24}[15:0]	Cb_{26}[15:0]
	Channel 1	Y[15:0]	Y_{20}[15:0]	Y_{22}[15:0]	Y_{24}[15:0]	Y_{26}[15:0]
	Channel 2	Cr[15:0]	Y_{21}[15:0]	Y_{23}[15:0]	Y_{25}[15:0]	Y_{27}[15:0]
Line 3	Channel 0	Cb[15:0]	Cr_{20}[15:0]	Cr_{22}[15:0]	Cr_{24}[15:0]	Cr_{26}[15:0]
	Channel 1	Y[15:0]	Y_{30}[15:0]	Y_{32}[15:0]	Y_{34}[15:0]	Y_{36}[15:0]
	Channel 2	Cr[15:0]	Y_{31}[15:0]	Y_{33}[15:0]	Y_{35}[15:0]	Y_{37}[15:0]

4.1.3 Source Window of Opportunity Generator

The source Window of Opportunity (WOP) generator creates valid data islands within the blanking regions.

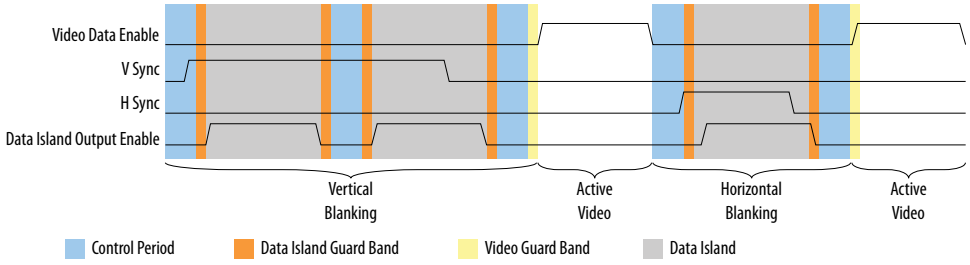
During active line region, the WOP generator creates a leading region to hold at least 12 period symbols that include eight preamble symbols. The generator also creates a trailing region to hold two data island trailing guard band symbols, at least 12 control period symbols that include eight preamble symbols and two video leading guard band symbols.

During vertical blanking region, the source cannot send more than 18 auxiliary packets consecutively. The WOP generator deasserts the data island output enable (aux_de) line after every 18th auxiliary packet for 32-symbol clocks.

The WOP generator also has an integral number of auxiliary packet cycles: 24 clocks when processing in 1-symbol mode, 16 clocks when processing in 2-symbol mode, and 8 clocks when processing in 4-symbol mode.

Figure 20. Typical Window of Opportunity

The figure below shows a typical output from the WOP generator.



4.1.4 Source Auxiliary Packet Encoder

Auxiliary packets are encoded by the source auxiliary packet encoder.

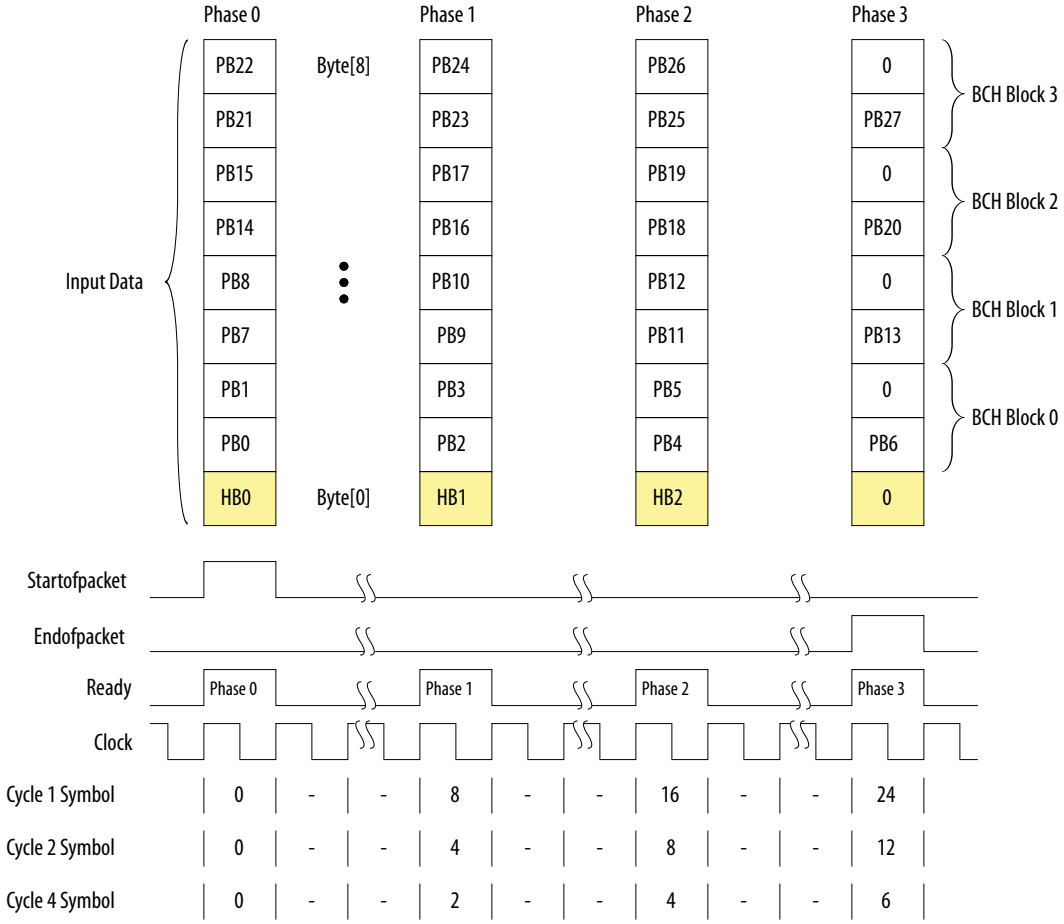
The auxiliary packets originate from a number of sources, which are multiplexed into the auxiliary packet encoder in a round-robin schedule. The auxiliary packet encoder converts a standard stream into the channel data format required by the TERC4 encoder.

The source propagates the WOP signal backwards through the stream ready signal.

The auxiliary packet encoder also calculates and inserts the Bose-Chaudhuri-Hocquenghem (BCH) error correction code.

Figure 21. Auxiliary Packet Encoder Input

The figure below shows the auxiliary packet encoder input from a 72-bit input data.

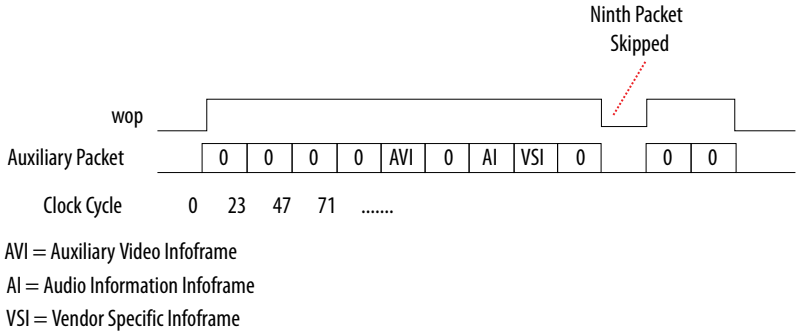


The encoder assumes the data valid input will remain asserted for the duration of a packet to complete. A packet is always 24 clocks (in 1-symbol mode), 12 clocks (in 2-symbol mode), or 6 clocks (in 4-symbol mode).

The encoder creates a NULL auxiliary packet if it doesn't detect a start-of-packet at the beginning of a packet boundary. In this case, you can consider the output of the encoder as a stream of NULL packets unless a valid packet is available.

Figure 22. Typical Auxiliary Packet Stream During Blanking Interval

The figure below shows a typical auxiliary packet stream in 1-symbol per clock mode, where 0 denotes a null packet.



4.1.5 Source Auxiliary Packet Generators

The source core uses various auxiliary packet generators. The packet generators convert the packet field inputs to the auxiliary packet stream format.

The packet generator propagates backpressure from the output ready signal to the input ready signal. The generator asserts the input valid signal when a packet is ready to be transmitted. The input valid signal remains asserted until the generator receives a ready acknowledgment.

4.1.6 Source Auxiliary Data Path Multiplexers

The auxiliary data path multiplexers provide paths for the various auxiliary packet generators.

The various auxiliary packet generators traverse a multiplexed routing path to the auxiliary packet encoder. The multiplexers obey a round-robin schedule and propagate backpressure.

4.1.7 Source Auxiliary Control Port

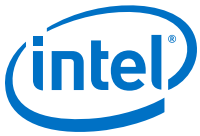
To simplify the user logic, the source core has control ports to send the most common auxiliary control packets.

These packets are: General Control Packet, Auxiliary Video Information (AVI) InfoFrame, HDMI Vendor Specific InfoFrame (VSI), and Audio InfoFrame.

The core sends the default values in the auxiliary packets. The default values allow the core to send video data compatible with the *HDMI Specification Ver.1.4b* with minimum description.

You can also override the generators using the customized input values. The override values replace the default values when the input checksum is non-zero.

The core sends the auxiliary control packets on the active edge of the V-SYNC signal to ensure that the packets are sent once per field.



4.1.7.1 Source General Control Packet

Table 6. Source General Control Packet Input Fields

This table lists the controllable bit-fields for the Source General Control Packet port.

Bit Field	Name	Comment				
gcp[3:0]	Color Depth (CD)	CD3	CD2	CD1	CD0	Color depth
		0	0	0	0	Color depth not indicated
		0	0	0	1	Reserved
		0	0	1	0	Reserved
		0	0	1	1	Reserved
		0	1	0	0	8 bpc or 24 bits per pixel (bpp)
		0	1	0	1	10 bpc or 30 bpp
		0	1	1	0	12 bpc or 36 bpp
		0	1	1	1	16 bpc or 48 bpp
		1	1	1	1	Reserved
gcp[4]	Set_AVMUTE	Refer to *HDMI Specification Ver.1.4b*.				
gcp[5]	Clear_AVMUTE	Refer to *HDMI Specification Ver.1.4b*.				

All other fields for the source GCP, (for example, pixel packing) are calculated automatically inside the core. You must provide the bit-field value in the table above through the source GCP port. The GCP on the auxiliary data port will always be filtered.

4.1.7.2 Source Auxiliary Video Information (AVI) InfoFrame

The HDMI core produces the captured AVI InfoFrame to simplify user applications.

Table 7. Auxiliary Video Information (AVI) InfoFrame

The table below lists the bit-fields for the AVI InfoFrame port bundle.

The signal bundle is clocked by `ls_clk`.

Bit-field	Name	Comment
7:0	Checksum	Checksum
9:8	S	Scan information
11:10	B	Bar info data valid
12	A0	Active information present
14:13	Y	RGB or YCbCr indicator
15	Reserved	Returns 0
19:16	R	Active format aspect ratio
21:20	M	Picture aspect ratio
23:22	C	Colorimetry (for example: ITU BT.601, BT.709)

continued...

Bit-field	Name	Comment
25:24	SC	Non-uniform picture scaling
27:26	Q	Quantization range
30:28	EC	Extended colorimetry
31	ITC	IT content
38:32	VIC	Video format identification code
39	Reserved	Returns 0
43:40	PR	Picture repetition factor
45:44	CN	Content type
47:46	YQ	YCC quantization range
63:48	ETB	Line number of end of top bar
79:64	SBB	Line number of start of bottom bar
95:80	ELB	Pixel number of end of left bar
111:96	SRB	Pixel number of start of right bar
112	Control	Disables the core from inserting the InfoFrame packet. • 1: The core does not insert `info_avi[111:0]`. The AVI InfoFrame packet on the auxiliary data port passes through. • 0: The core inserts `info_avi[111:0]` when checksum field (`info_avi[7:0]`) is non-zero. The core sends default values when checksum field (`info_avi[7:0]`) is zero. The core filters the AVI InfoFrame packet on the auxiliary data port.

4.1.7.3 Source HDMI Vendor Specific InfoFrame (VSI)

The core transmits a HDMI Vendor Specific InfoFrame once per field.

Table 8. HDMI Vendor Specific InfoFrame Bit-Fields

The table below lists the bit-fields for VSI.

The signal bundle is clocked by `ls_clk`.

Bit-field	Name	Comment
4:0	Length	Length = Nv
12:5	Checksum	Checksum
36:13	IEEE	24-bit IEEE registration identified (0×000C03)
41:37	Reserved	All 0
44:42	HDMI_Video_Format	HDMI video format
52:45	HDMI_VIC	HDMI proprietary video format identification code
57:53	Reserved	All 0
60:58	3D_Ext_Data	3D extended data
61	Control	Disables the core from inserting the InfoFrame packet.

continued...

Bit-field	Name	Comment
		• 1: The core does not insert `info_vsi[60:0]`. The VSI InfoFrame packet on the auxiliary data port passes through. • 0: The core inserts `info_vsi[60:0]` when checksum field (`info_vsi[12:5]`) is non-zero. The core sends default values when checksum field (`info_vsi[12:5]`) is zero. The core filters the VSI InfoFrame packet on the auxiliary data port.

Note: If the checksum input to the port is zero, the core uses a default value of zero for each bit-field.

4.1.7.4 Source Audio InfoFrame (AI)

The core transmits an Audio InfoFrame once per field.

Table 9. Source Audio InfoFrame Bundle Bit-Fields

The table below lists the signal bit-fields.

The signal bundle is clocked by `ls_clk`.

Bit-field	Name	Comment
7:0	Checksum	Checksum
10:8	CC	Channel count
11	Reserved	Returns 0
15:12	CT	Audio format type
17:16	SS	Bits per audio sample
20:18	SF	Sampling frequency
23:21	Reserved	Returns 0
31:24	CXT	Audio format type of the audio stream
39:32	CA	Speaker location allocation FL, FR
41:40	LFEPBL	LFE playback level information, dB
42	Reserved	Returns 0
46:43	LSV	Level shift information, dB
47	DM_INH	Down-mix inhibit flag
48		Disables the core of the InfoFrame packets from inserting.

continued...

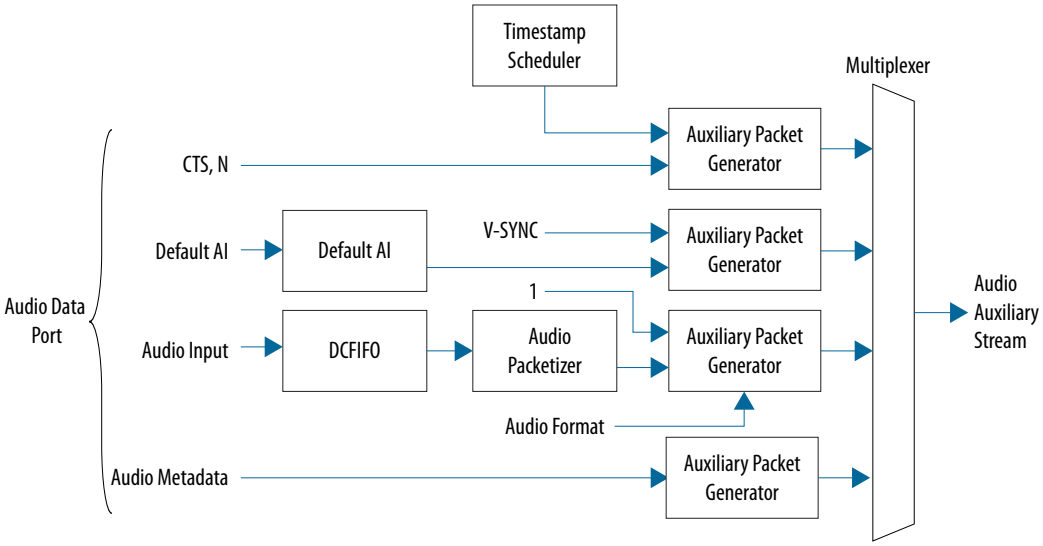
Bit-field	Name	Comment
		• 1: The core does not insert `audio_info_ai[47:0]`. The Audio InfoFrame packet on the auxiliary data port passes through. • 0: The core inserts `audio_info_ai[47:0]` when checksum field (`audio_info_ai[7:0]`) is non-zero. The core sends default values when checksum field (`audio_info_ai[7:0]`) is zero. The core filters the Audio InfoFrame packet on the auxiliary data port.

Note: If the checksum input to the port is zero, the core uses a default value of zero for each bit-field.

4.1.8 Source Audio Encoder

Audio transport requires three packet types: Audio Timestamp InfoFrame, Audio Information InfoFrame, and Audio Sample Data.

Figure 23. Source Audio Encoder



The Audio Timestamp InfoFrame packet contains the CTS and N values. You need to provide these values. The core schedules this packet to be sent every ms. The scheduler uses the `audio_clk` and *N* value to determine a 1-ms interval.

The core sends the Audio Information InfoFrame packet on the active edge of the V-SYNC signal.

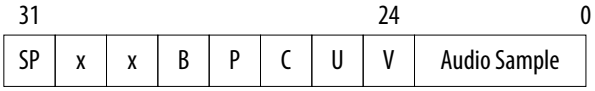
The Audio Sample Data packet queues on a DCFIFO. The core also uses the DCFIFO to synchronize its clock to `ls_clk`. The Audio Packetizer packs the audio sample data into the Audio Sample packets according to the specified audio format. An Audio

Sample packet can contain up to 4 audio samples, based on the required audio sample clock. The core sends the Audio Sample packets whenever there is an available slot in the auxiliary packet stream.

The `audio_data` port is always at a fixed value of 256 bits and the `audio_de` port is always fixed to 1 bit. For audio channels fewer than 8, insert 0 to the audio data of the unused audio channels.

The 32-bit audio data is packed in IEC-60958 standard. The least significant word is the left channel sample.

Figure 24. Audio Data Packing



The fields are defined as:

SP : Sample Present
x : Not Used
B : Start of 192-bit IEC-60958 Channel Status
P : Parity Bit
C : Channel Status
U : User Data Bit
V : Valid Bit

The Audio Timestamp InfoFrame and Audio Sample Data packets on the Auxiliary Data Port are not filtered by the source. You must filter these packets externally if you want to loop back the auxiliary data stream from the sink. The Audio Information InfoFrame packet on the Auxiliary Data Port will be filtered by the source if the most significant bit of `audio_info_ai` port is set to 0.

4.1.8.1 HDMI Audio Format

The HDMI IP core uses the HDMI audio formats to transport payload data.

Table 10. Definition of HDMI Audio Format

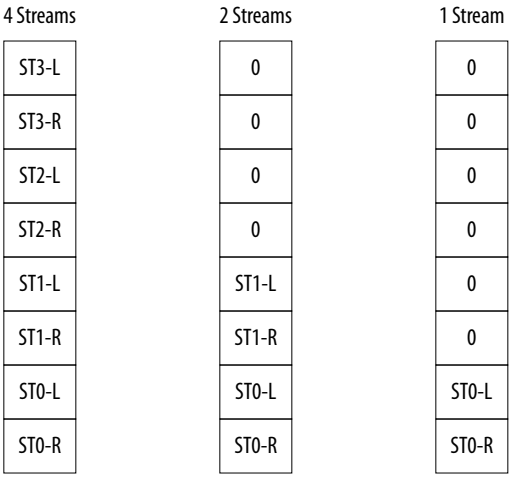
Value	Name	Description
0	Linear Pulse-Code Modulation (LPCM)	HDMI packet type 2 transports payload data
1	One-Bit Audio	HDMI packet type 7 transports payload data (not supported)
2	Direct Stream Transport (DST) Audio	HDMI packet type 8 transports payload data (not supported)
3	High Bit Rate (HBR)	HDMI packet type 9 transports payload data
4	3D (LPCM)	HDMI packet type 11 transports payload data (not supported)
5	3D (One-Bit)	HDMI packet type 12 transports payload data (not supported)
6	Multi-Stream Audio (MST) for LPCM	HDMI packet type 14 transports payload data
7	MST for One-Bit Audio	HDMI packet type 15 transports payload data (not supported)
8–15	—	Reserved

In the LPCM format, the HDMI source accepts 2 to 8 channels. . The `Sample Present` bit determines whether to use 2-channel or 8-channel layout. If the `Sample Present` bit from Channel 0 or 1 is high, then audio interface uses the 2-channel layout. If otherwise, the audio interface uses the 8-channel layout. The IP core ignores the `Parity`, `Channel Status`, `User Data`, and `Valid` bits if the `Sample Present` bit is 0.

In the HBR format, the sample packet data is identical to the LPCM format. In HBR mode, the HDMI source transmits 8 samples per clock. The core transmits the HBR audio packets using AUX packet header number 9.

In the MST format, the sample packet data is also identical to the LPCM format. The MST mode enables a source to send up to 4 streams of audio to a sink device. The HDMI source sends 1, 2, or 4 streams. When the source sends fewer than 4 streams, you must set the input audio data to zero.

Figure 25. MST Audio Format



4.2 Source Interfaces

The table lists the source's port interfaces.

Table 11. Source Interfaces

N is the number of symbols per clock.

Interface	Port Type	Clock Domain	Port	Direction	Description
Reset	Reset	N/A	`reset`	Input	Main asynchronous reset input.
Clock	Clock	N/A	`ls_clk`	Input	Link speed clock input. 8/8 (1x), 10/8 (1.25x), 12/8 (1.5x), or 16/8 (2x) times the `vid_clk` according to color depth. This signal connects to the transceiver output clock.
	Clock	N/A	`vid_clk`	Input	Video data clock input.

continued...

Interface	Port Type	Clock Domain	Port	Direction	Description
					• 1 symbol per clock mode = video pixel clock • 2 symbols per clock mode = half the pixel clock • 4 symbols per clock mode = quarter the pixel clock
	Clock	N/A	audio_clk	Input	Audio clock input.
Video Data Port	Conduit	vid_clk	vid_data[N*48-1:0]	Input	Video 48-bit pixel data input port. • In 2 symbols per clock (N=2) mode, this port accepts two 48-bit pixels per clock. • In 4 symbols per clock (N=4) mode, this port accepts four 48-bit pixels per clock.
	Conduit	vid_clk	vid_de[N-1:0]	Input	Video data enable input that indicates active picture region.
	Conduit	vid_clk	vid_hsync[N-1:0]	Input	Video horizontal sync input.
	Conduit	vid_clk	vid_vsync[N-1:0]	Input	Video vertical sync input.
TMDS Data Port	Conduit	ls_clk	out_b[10*N-1:0]	Output	TMDS encoded blue channel output.
	Conduit	ls_clk	out_r[10*N-1:0]	Output	TMDS encoded red channel output.
	Conduit	ls_clk	out_g[10*N-1:0]	Output	TMDS encoded green channel output.
	Conduit	ls_clk	out_c[10*N-1:0]	Output	TMDS encoded clock channel output.
Auxiliary Data Port	Conduit	ls_clk	aux_ready	Output	Auxiliary data channel valid output.
	Conduit	ls_clk	aux_valid	Input	Auxiliary data channel valid input.
	Conduit	ls_clk	aux_data[71:0]	Input	Auxiliary data channel data input.
	Conduit	ls_clk	aux_sop	Input	Auxiliary data channel start-of-packet input.
	Conduit	ls_clk	aux_eop	Input	Auxiliary data channel end-of-packet input.
Encoder Control Port	Conduit	ls_clk	mode	Input	Encoding mode input. • 0 = DVI • 1 = HDMI

continued...

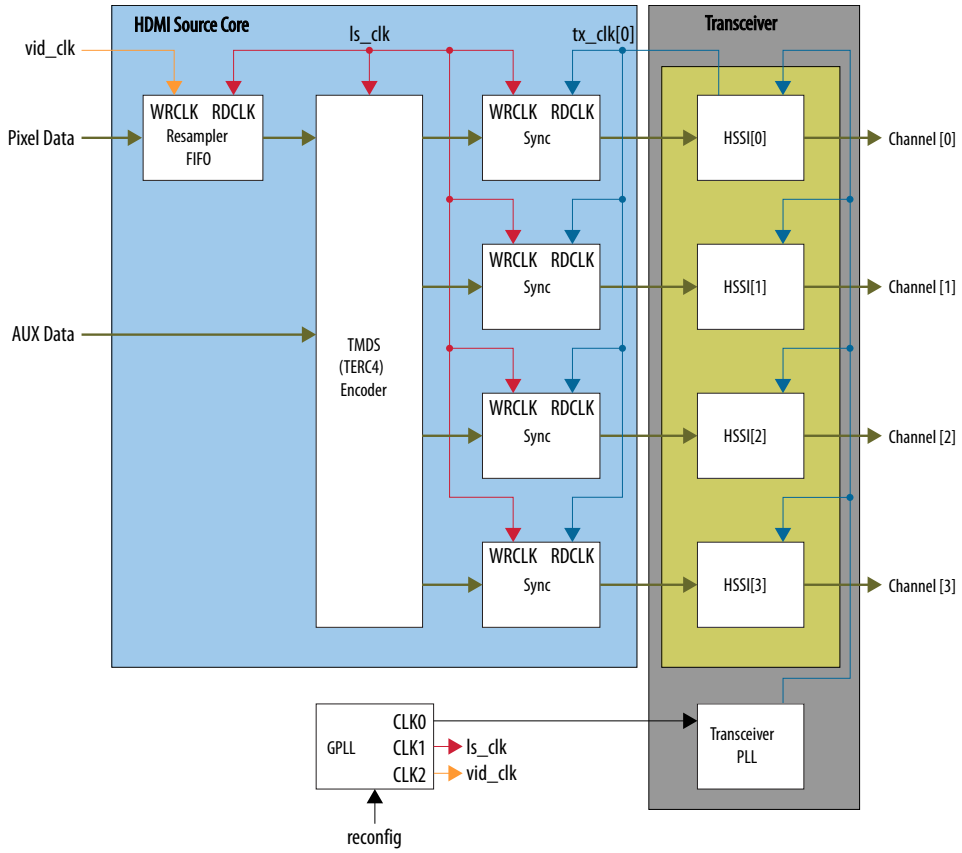
Interface	Port Type	Clock Domain	Port	Direction	Description
	Conduit	ls_clk	TMDS_Bit_clock_Ratio	Input	• 0 = (TMDS bit period) / (TMDS clock period) ratio is 1/10 • 1 = (TMDS bit period) / (TMDS clock period) ratio is 1/40
	Conduit	ls_clk	Scrambler_Enable	Input	• 0 = Instructs the source device not to perform scrambling • 1 = Instructs the source device to perform scrambling
	Conduit	ls_clk	ctrl[6*N-1:0]	Input	DVI control side-band inputs to override the necessary control and synchronization data in the green and red channels.
Audio Port	Conduit	audio_clk	audio_CTS[19:0]	Input	Audio CTS value input.
	Conduit	audio_clk	audio_N[19:0]	Input	Audio N value input.
	Conduit	audio_clk	audio_data[255:0]	Input	Audio data input.
	Conduit	audio_clk	audio_de	Input	Audio data valid input.
	Conduit	audio_clk	audio_mute	Input	Audio mute input.
	Conduit	audio_clk	audio_info_ai[48:0]	Input	Audio InfoFrame input bundle input.
	Conduit	audio_clk	audio_metadata[165:0]	Input	Carries additional information related to 3D audio and multi-stream audio.
	Conduit	audio_clk	audio_format[4:0]	Input	Indicates the audio format to be transmitted.
Auxiliary Control Port	Conduit	ls_clk	gcp[5:0]	Input	General Control Packet.
	Conduit	ls_clk	info_avi[112:0]	Input	Auxiliary Video Information InfoFrame input.
	Conduit	ls_clk	info_vsi[61:0]	Input	Vendor Specific Information InfoFrame input.
Misc.	Conduit	–	version[31:0]	Output	Version of the HDMI core.

4.3 Source Clock Tree

The source uses various clocks.

Figure 26. Source Clock Tree

The figure shows how the different clocks connect in the source core.



The pixel data clocks into the core at the pixel clock (vid_clk). This same clock derives the required link speed clock (ls_clk), which is used to drive the transceiver phase-locked loop (PLL) input. The ls_clk depends on the color bits per pixel (bpp).

Because the transceiver is in bonding mode, the HDMI source core uses tx_clk[0] to clock the data from the source core in the ls_clk domain into the transceiver in the tx_clk[0] domain.

For HDMI source, you must instantiate 4 transmitter channels: 3 channels to transmit data and 1 channel to transmit clock information.

You must connect the core ls_clk to the transceiver clock output, which performs the TMDS and TERC4 encoding. The auxiliary data clocks into the core at the ls_clk rate.

Related Links

HDMI Hardware Demonstration on page 52
For more information about the transmitter and receiver channels.

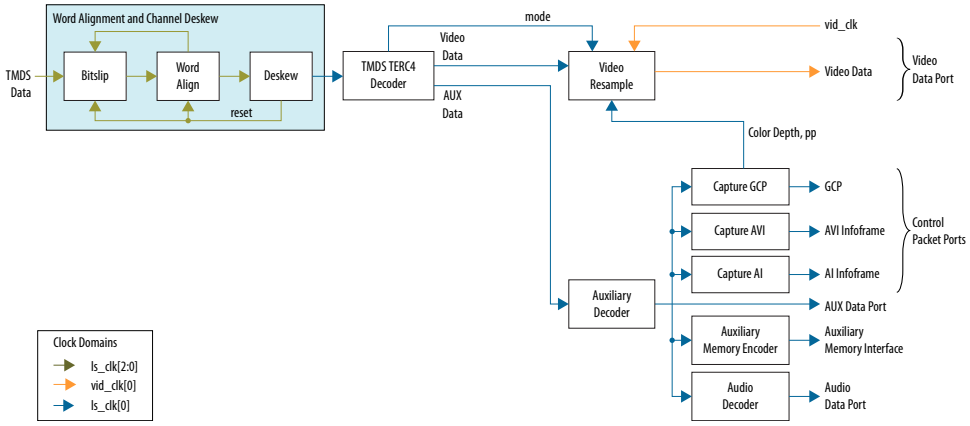
5 HDMI Sink

5.1 Sink Functional Description

The HDMI sink core provides direct connection to the Transceiver Native PHY through a 10-bit, 20-bit, or 40-bit parallel data path.

Figure 27. HDMI Sink Signal Flow Diagram

The figure below shows the flow of the HDMI sink signals. The figure shows the various clocking domains used within the core.



The sink core provides three 10-bit, 20-bit, or 40-bit data input paths corresponding to the color channels. The sink core clocks the three 10-bit, 20-bit, or 40-bit channels from the transceiver outputs using the respective transceiver clock outputs.

- Blue channel: 0
- Green channel: 1
- Red channel: 2

5.1.1 Sink Channel Word Alignment and Deskew

The input stage of the sink is responsible for synchronizing the incoming parallel data channels correctly. The synchronization is split to two stages: word alignment and channel deskew.

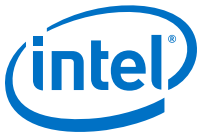
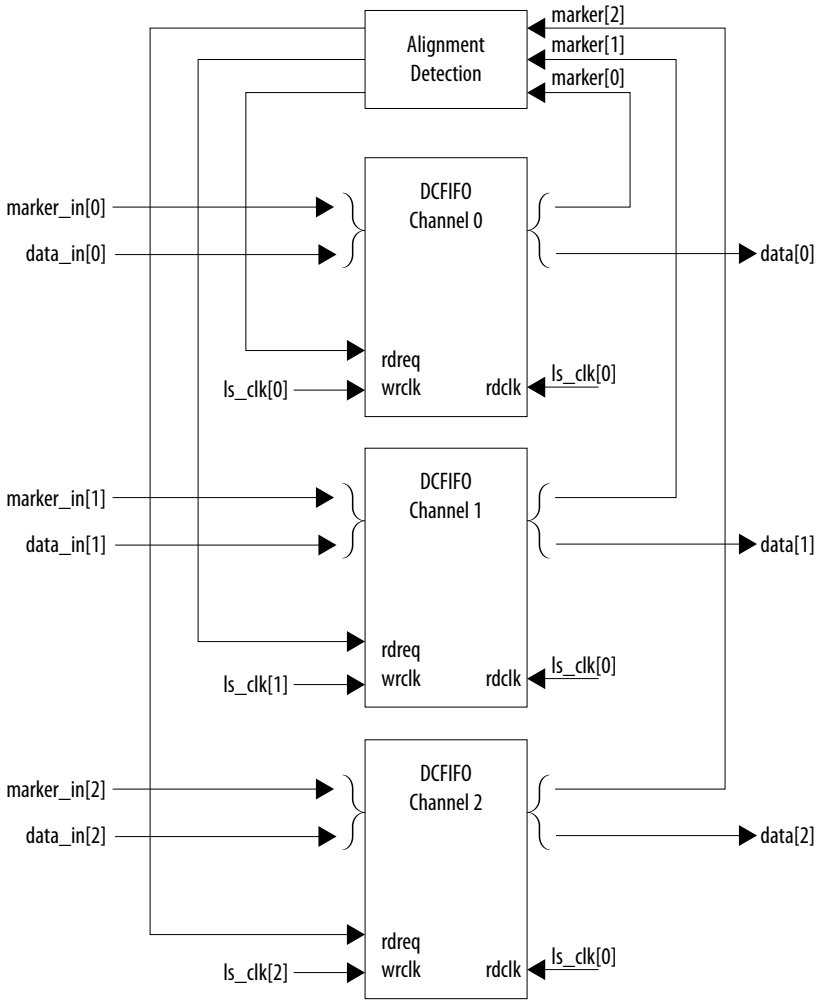


Table 12. Synchronization Stages

Stage	Description
Word Alignment	• Correctly aligns the incoming parallel data to word boundaries using bit-slip technique. • TMDS encoding does not guarantee unique control codes, but the core can still use the sequence of continuous symbols found in data and video preambles to align. • The alignment algorithm searches for 12 consecutive 0×54 or 0×ab corresponding to the data and video preambles. *Note:* The preambles are also present in digital video interface (DVI) coding. • The alignment logic asserts a marker indicator when the 12 consecutive signals are detected. • Similarly, the logic infers alignment loss when 8K symbol clocks elapse without a single marker assertion.
Channel Deskew	• When the data channels are aligned, the core then attempts to deskew each channel. • The sink core deskews at the rising edge of the marker insertion. • For every correct deskewed lane, the marker insertion will appear in all three TMDS encoded streams. • The sink core deskews using three dual-clock FIFOs. • The dual-clock FIFOs also synchronize all three data streams to the blue channel clock to be used later throughout the decoder core.

Figure 28. Channel Deskew DCFIFO Arrangement

The figure below shows the signal flow diagram of the deskew logic.



The FIFO read signal of the channels is normally asserted. The sink core deasserts a particular FIFO read signal if a marker appears at its output and not in the other two FIFO outputs. By deasserting, the sink core stalls the data stream for sufficient cycles to remove the channel skew. If any of the FIFO channels overflow, the sink core asserts a reset signal which propagates backwards to the word alignment logic.

5.1.2 Sink TMDS/TERC4 Decoder

The sink TMDS/TERC4 decoder follows the HDMI/DVI specification. The video data is encoded using the TMDS algorithm and auxiliary data is encoded using TERC4 algorithm.

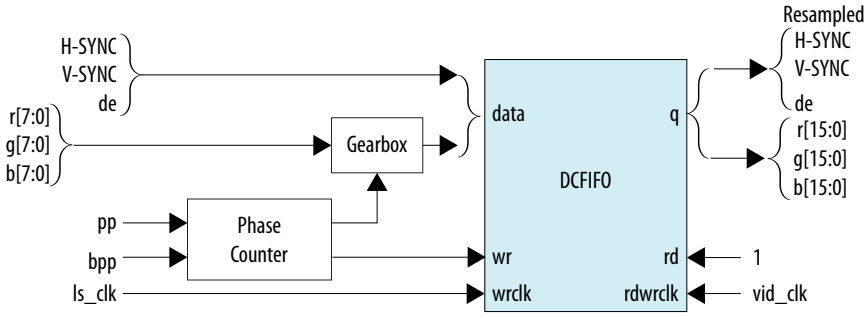
The sink core feeds the aligned channels into the TMDS/TERC4 decoder. You can parameterize the decoder to operate in 1, 2, or 4 TMDS symbols per clock. If you choose 2 or 4 TMDS symbols per clock, the decoder will produce 2 or 4 decoded symbols per clock. The decoded symbols per clock output supports high pixel clock resolutions on low-end FPGA devices.

5.1.3 Sink Video Resampler

The video resampler consists of a gearbox and a dual-clock FIFO (DCFIFO).

The gearbox converts 8-bpc data to 8-, 10-, 12- or 16-bpc data based on the current color depth. The GCP conveys the color depth information.

Figure 29. Sink Resampler Signal Flow Diagram



The resampler adheres to the recommended phase count method described in *HDMI Specification Ver.1.4b*.

- To keep the source and sink resamples synchronized, the source must send the phase-packing (pp) value to the sink during the vertical blanking phase, using the general control packet.
- The pp corresponds to the phase of the last pixel in the last active video line.
- The phase-counter logic compares its own pp value to the pp value received in the general control packet and *slips* the phase count if the two pp values do not agree.

The output from the resampler is fixed at 16 bpc. When the resampler operates in lower color depths, the low order bits are zero.

5.1.4 Sink Auxiliary Decoder

The sink core decodes the auxiliary data path into a 72-bit wide standard packet stream. The stream contains a valid, start-of-packet (SOP) and end-of-packet (EOP) marker.

Table 13. Auxiliary Packet Memory Map

This table lists the addresses corresponding to the captured packets.

Memory Start Address	Packet Name
0	NULL PACKET
4	Audio Clock Regeneration (N/CTS)
8	Audio Sample
12	General Control
16	ACP Packet
20	ISRC1 Packet
	continued...

Memory Start Address	Packet Name
24	ISRC2 Packet
28	One Bit Audio Sample Packet 5.3.9
32	DST Audio Packet
36	High Bit rate (HBR) Audio Stream Packet
40	Gamut Metadata Packet
44	3D Audio Sample Packet
48	One Bit 3D Audio Sample Packet
52	Audio Metadata Packet
56	Multi-Stream Audio Sample Packet
60	One Bit Multi-Stream Audio Sample Packet
64	Vendor-Specific InfoFrame
68	AVI InfoFrame
72	Source Product Descriptor InfoFrame
76	Audio InfoFrame
80	MPEG Source InfoFrame
84	TSC VBI InfoFrame
88	Dynamic Range and Mastering InfoFrame

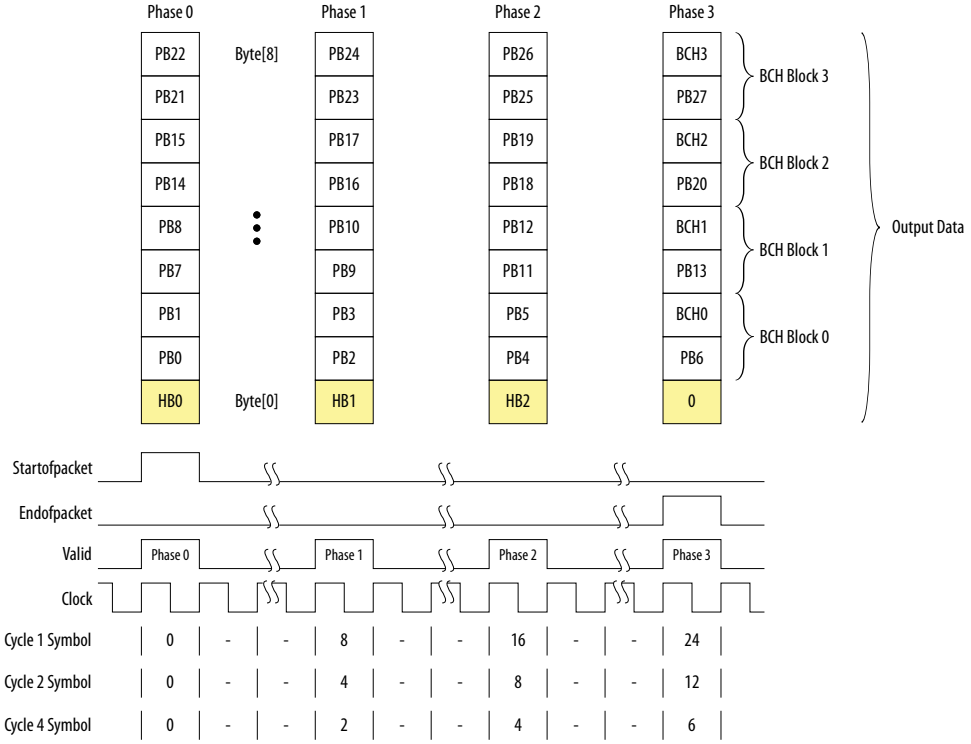
Table 14. Packet Payload Data Byte

This table shows the representation of each packet payload data byte.

Word Offset	Byte Offset								
	8	7	6	5	4	3	2	1	0
0	PB22	PB21	PB15	PB14	PB8	PB7	PB1	PB0	HB0
1	PB24	PB23	PB17	PB16	PB10	PB9	PB3	PB2	HB1
2	PB26	PB25	PB19	PB18	PB12	PB11	PB5	PB4	HB2
3	BCH3	PB27	BCH2	PB20	BCH1	PB13	BCH0	PB6	HBCH0

Figure 30. Auxiliary Data Stream Signal

The figure below shows the relationship between the data bit-field and its clock cycle based on 1-, 2-, or 4-symbol per clock mode.



The data output at EOP contains the received BCH error correcting code. The sink core does not perform any error correction within the core. The auxiliary data is available outside the core.

Note: You can find the bit-field nomenclature in the *HDMI Specification Ver.2.0*.

5.1.5 Sink Auxiliary Packet Capture

The auxiliary streams transfer auxiliary packets.

The auxiliary packets can carry 15 different packet types.

The module produces 4 valid signals to simplify the user logic.

To simplify user applications and minimize external logic, the HDMI core captures 3 different packet types and decodes the audio sample data. These packets are: General Control Packet, Auxiliary Video Information (AVI) InfoFrame, and HDMI Vendor Specific InfoFrame (VSI).

5.1.5.1 Sink General Control Packet

Table 15. General Control Packet Input Fields

Bit Field	Name	Comment				
gcp[3:0]	Color Depth (CD)	CD3	CD2	CD1	CD0	Color depth
		0	0	0	0	Color depth not indicated
		0	0	0	1	Reserved
		0	0	1	0	Reserved
		0	0	1	1	Reserved
		0	1	0	0	8 bpc or 24 bpp
		0	1	0	1	10 bpc or 30 bpp
		0	1	1	0	12 bpc or 36 bpp
		0	1	1	1	16 bpc or 48 bpp
		1	1	1	1	Reserved
gcp[4]	Set_AVMUTE	Refer to *HDMI Specification Ver.1.4b*				
gcp[5]	Clear_AVMUTE	Refer to *HDMI Specification Ver.1.4b*				

5.1.5.2 Sink Auxiliary Video Information (AVI) InfoFrame

The HDMI core produces AVI InfoFrame to simplify user applications.

Table 16. Auxiliary Video Information (AVI) InfoFrame Bit-Fields

The table below lists the bit-fields for the AVI InfoFrame port bundle.

The signal bundle is clocked by `ls_clk`.

Bit-field	Default Value (Hexadecimal)	Name	Comment
7:0	67	Checksum	Checksum
9:8	0	S	Scan information
11:10	0	B	Bar info data valid
12	0	A0	Active information present
14:13	0	Y	RGB or YCbCr indicator
15	0	Reserved	Returns 0
19:16	8	R	Active format aspect ratio
21:20	0	M	Picture aspect ratio
23:22	0	C	Colorimetry (for example: ITU BT.601, BT.709)
25:24	0	SC	Non-uniform picture scaling
27:26	0	Q	Quantization range
30:28	0	EC	Extended colorimetry

continued...

Bit-field	Default Value (Hexadecimal)	Name	Comment
31	0	ITC	IT content
38:32	00	VIC	Video format identification code
39	0	Reserved	Returns 0
43:40	0	PR	Picture repetition factor
45:44	0	CN	Content type
47:46	0	YQ	YCC quantization range
63:48	0000	ETB	Line number of end of top bar
79:64	0000	SBB	Line number of start of bottom bar
95:80	0000	ELB	Pixel number of end of left bar
111:96	0000	SRB	Pixel number of start of right bar

5.1.5.3 Sink HDMI Vendor Specific InfoFrame (VSI)

The core produces the captured HDMI Vendor Specific InfoFrame to simplify user applications.

Table 17. HDMI Vendor Specific InfoFrame Bit-Fields

The table below lists the bit-fields for VSI.

The signal bundle is clocked by `ls_clk`.

Bit-field	Default Value (Hexadecimal)	Name	Comment
4:0	06	Length	Length = Nv
12:5	69	Checksum	Checksum
36:13	000C03	IEEE	24-bit IEEE registration identified (0x000C03)
41:37	00	Reserved	All 0
44:42	0	HDMI_Video_Format	HDMI video format
52:45	00	HDMI_VIC	HDMI proprietary video format identification code
57:53	00	Reserved	All 0
60:58	0	3D_Ext_Data	3D extended data

5.1.6 Sink Auxiliary Data Port

The auxiliary port is attached to external memory. This port allows you to write packets to memory for use outside the HDMI core.

The core calculates the address for the data port using the header byte of the received packet. The core writes packet types 0–15 into a contiguous memory region.

Figure 31. Typical Application of AUX Packet Register Interface

The figure below shows a typical application of the auxiliary data port.

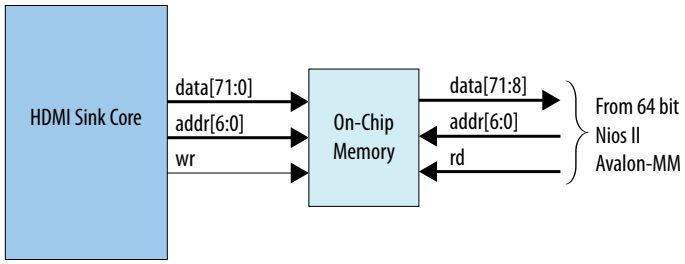


Table 18. Auxiliary Packet Memory Map

Memory Start Address	Packet Name
0	NULL PACKET
4	Audio Clock Regeneration (N/CTS)
8	Audio Sample
12	General Control
16	ACP Packet
20	ISRC1 Packet
24	ISRC2 Packet
28	One Bit Audio Sample Packet 5.3.9
32	DST Audio Packet
36	High Bitrate (HBR) Audio Stream Packet
40	Gamut Metadata Packet
44	3D Audio Sample Packet
48	One Bit 3D Audio Sample Packet
52	Audio Metadata Packet
56	Multi-Stream Audio Sample Packet
60	One Bit Multi-Stream Audio Sample Packet
64	Vendor-Specific InfoFrame
68	AVI InfoFrame
72	Source Product Descriptor InfoFrame
76	Audio InfoFrame
80	MPEG Source InfoFrame
84	TSC VBI InfoFrame
88	Dynamic Range and Mastering InfoFrame

Table 19. Packet Payload Data Byte

The table below lists the representation of each packet payload data byte.

Word Offset	Byte Offset								
	8	7	6	5	4	3	2	1	0
0	PB22	PB21	PB15	PB14	PB8	PB7	PB1	PB0	HB0
1	PB24	PB23	PB17	PB16	PB10	PB9	PB3	PB2	HB1
2	PB26	PB25	PB19	PB18	PB12	PB11	PB5	PB4	HB2
3	BCH3	PB27	BCH2	PB20	BCH1	PB13	BCH0	PB6	HBCH0

Note: The packet fields (PB0-PB26) are described in the HDMI 1.4b Specification (Chapter 8.2.1).

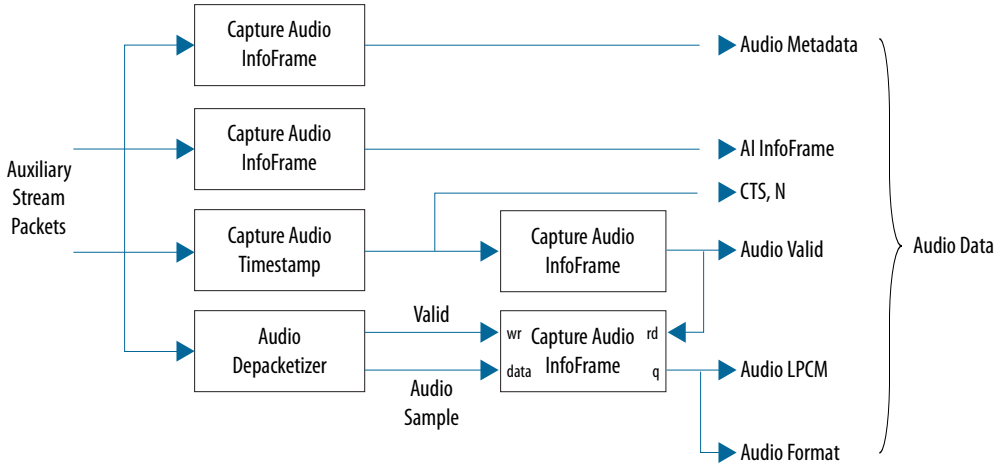
5.1.7 Sink Audio Decoding

The sink core sends the audio data using auxiliary packets. You can use three packet types in transporting audio: Audio InfoFrame, Audio Timestamp, and Audio Sample Data.

The Audio InfoFrame packet is not used within the core but it is captured and presented outside the core.

The Audio Timestamp packet transmits the CTS and N values required to synthesize the audio sample clock. The core also makes the CTS and N values available outside the core. The audio clock synthesizer uses a phase-counter to recover the audio sample rate.

Figure 32. Audio Decoder Signal Flow



The output from the audio clock synthesizer generates a valid pulse at the same rate as the audio sample clock used in the HDMI source device. This valid pulse is available outside the core as an audio sample valid signal. This signal reads from a FIFO, which governs the rate of audio samples. The audio depacketizer drives the input to the FIFO.

The audio depacketizer extracts the 32-bit audio sample data from the incoming Audio Sample packets. The Audio Sample packets can hold from one to four sample data values. The audio format indicates the format of the received audio data.

Table 20. Definition of HDMI Sink Audio Format

Value	Name	Description
0	LPCM	HDMI packet type 2 transports payload data
1	One-Bit Audio	HDMI packet type 7 transports payload data (not supported)
2	DST Audio	HDMI packet type 8 transports payload data (not supported)
3	HBR	HDMI packet type 9 transports payload data
4	3D (LPCM)	HDMI packet type 11 transports payload data (not supported)
5	3D (One-Bit)	HDMI packet type 12 transports payload data (not supported)
6	MST (LPCM)	HDMI packet type 14 transports payload data
7	MST (One-Bit)	HDMI packet type 15 transports payload data (not supported)
8–15	—	Reserved

5.1.7.1 HDMI Audio Format

The HDMI IP core uses the HDMI audio formats to transport payload data.

Table 21. Definition of HDMI Audio Format

Value	Name	Description
0	Linear Pulse-Code Modulation (LPCM)	HDMI packet type 2 transports payload data
1	One-Bit Audio	HDMI packet type 7 transports payload data (not supported)
2	Direct Stream Transport (DST) Audio	HDMI packet type 8 transports payload data (not supported)
3	High Bit Rate (HBR)	HDMI packet type 9 transports payload data
4	3D (LPCM)	HDMI packet type 11 transports payload data (not supported)
5	3D (One-Bit)	HDMI packet type 12 transports payload data (not supported)
6	Multi-Stream Audio (MST) for LPCM	HDMI packet type 14 transports payload data
7	MST for One-Bit Audio	HDMI packet type 15 transports payload data (not supported)
8–15	—	Reserved

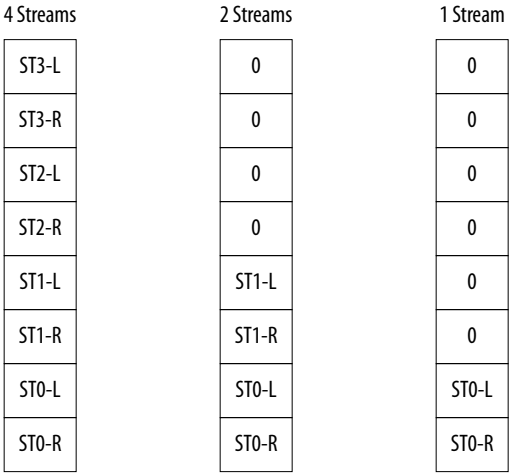
In the LPCM format, the HDMI source accepts 2 to 8 channels. . The `Sample Present` bit determines whether to use 2-channel or 8-channel layout. If the `Sample Present` bit from Channel 0 or 1 is high, then audio interface uses the 2-channel

layout. If otherwise, the audio interface uses the 8-channel layout. The IP core ignores the `Parity`, `Channel Status`, `User Data`, and `Valid` bits if the `Sample Present` bit is 0.

In the HBR format, the sample packet data is identical to the LPCM format. In HBR mode, the HDMI source transmits 8 samples per clock. The core transmits the HBR audio packets using AUX packet header number 9.

In the MST format, the sample packet data is also identical to the LPCM format. The MST mode enables a source to send up to 4 streams of audio to a sink device. The HDMI source sends 1, 2, or 4 streams. When the source sends fewer than 4 streams, you must set the input audio data to zero.

Figure 33. MST Audio Format



5.1.7.2 Audio InfoFrame

The sink produces the received Audio InfoFrame (AI) to simplify user applications.

Table 22. Audio InfoFrame Bundle Bit Fields

This table defines the signal bit fields. `ls_clk` clocks the signal bundle.

Bit Field	Name	Description
7:0	Checksum	Checksum
10:8	CC	Channel count
11	Reserved	Returns zero
15:12	CT	Audio format type
17:16	SS	Bits-per-audio sample
20:18	SF	Sampling frequency
23:21	Reserved	Returns zero
31:24	CXT	Audio format type of the audio stream
39:32	CA	Speaker location allocation: front left (FL), front right (FR)

continued...

Bit Field	Name	Description
41:40	LFEPBL	Low-frequency effects (LFE) playback level information, Decibel (dB)
42	Reserved	Returns zero
46:43	LSV	Level shift information, dB
47	DM_INH	Down-mix inhibit flag

5.1.7.3 Audio Metadata

The HDMI 2.0 specification introduces the Audio Metadata (AM) Packet. The Audio Metadata packet manages the Multi-Stream and 3D audio sample packets.

Table 23. Audio Metadata Bundle Bit Fields

This table defines the signal bit fields.

Bit Field	Name	Description
0	3D_AUDIO	• 1 = Transmits 3D audio • 0 = Transmits MST
2:1	NUM_VIEWS	Indicates the number of views for an MST stream
4:3	NUM_AUDIO_STR	Number of audio streams
164:5	Payload data	Corresponds to PB0 to PB19 of the Metadata packets.
165	ACTIVE	When asserted, the core never sends the Metadata.

Note: For more information, refer to the *HDMI 2.0 Specification, Chapter 8.3 Audio Metadata Packet*.

5.2 Sink Interfaces

The table lists the sink's port interfaces.

Table 24. Sink Interfaces

N is the number of symbols per clock.

Interface	Port Type	Clock Domain	Port	Direction	Description
Reset	Reset	N/A	`reset`	Input	Main asynchronous reset input. *Note:* Resetting the input will reset the SCDC register.
Clock	Clock	N/A	`ls_clk[2:0]`	Input	Link speed clock input. These clocks correspond to the `in_r`, `in_g`, and `in_b` TMDS encoded data inputs.
	Clock	N/A	`vid_clk`	Input	Video data clock input.

continued...

Interface	Port Type	Clock Domain	Port	Direction	Description
					Typically, 8/8, 8/10, 8/12, 8/16 times the ls_clk according to color depth (see General Control Packet output).
Video Data Port	Conduit	vid_clk	vid_data[N*48-1:0]	Output	Video 48-bit pixel data output port. In 2 symbols per clock (N=2) mode, this port produces two 48-bit pixels per clock. In 4 symbols per clock (N=4) mode, this port produces four 48-bit pixels per clock.
	Conduit	vid_clk	vid_de[N-1:0]	Output	Video data enable output that indicates active picture region.
	Conduit	vid_clk	vid_hsync[N-1:0]	Output	Video horizontal sync output.
	Conduit	vid_clk	vid_vsync[N-1:0]	Output	Video vertical sync output.
	Conduit	vid_clk	locked[2:0]	Output	Indicates that the HDMI sink core is locked to the TMDS signals. Each bit represents a color channel.
	Conduit	vid_clk	vid_lock	Output	Asserted when the received video data is determined to be stable and repetitive.
TMDS Data Port	Conduit	ls_clk[0]	in_b[N*10-1:0]	Input	TMDS encoded blue channel input.
	Conduit	ls_clk[1]	in_g[N*10-1:0]	Input	TMDS encoded green channel input.
	Conduit	ls_clk[2]	in_r[N*10-1:0]	Input	TMDS encoded red channel input.
	Conduit	ls_clk[2:0]	in_lock[2:0]	Input	Ready signal from the transceiver reset controller that indicates the transceivers are locked. Each bit represents a color channel.
Auxiliary Data Port	Conduit	ls_clk[0]	aux_valid	Output	Auxiliary data channel valid output.
	Conduit	ls_clk[0]	aux_data[71:0]	Output	Auxiliary data channel data output.
	Conduit	ls_clk[0]	aux_sop	Output	Auxiliary data channel start-of-packet input.
	Conduit	ls_clk[0]	aux_eop	Output	Auxiliary data channel end-of-packet output.

continued...

Interface	Port Type	Clock Domain	Port	Direction	Description
	Conduit	ls_clk[0]	aux_error	Output	Asserted when there is auxiliary data channel CRC error.
Decoder Control Port	Conduit	ls_clk[0]	TMDS_Bit_clock_Ratio	Output	• 0 = (TMDS bit period) / (TMDS clock period) ratio is 1/10 • 1 = (TMDS bit period) / (TMDS clock period) ratio is 1/40
	Conduit	ls_clk[0]	ctrl[N*6-1:0]	Output	DVI Control side-band signals that show the data that overwrite the control and synchronization character in the green and red channels.
	Conduit	ls_clk[0]	mode	Output	Encoding mode • 0 = DVI • 1 = HDMI
Audio Port	Conduit	ls_clk[0]	audio_CTS[19:0]	Output	Audio CTS value output.
	Conduit	ls_clk[0]	audio_N[19:0]	Output	Audio N value output.
	Conduit	ls_clk[0]	audio_data[255:0]	Output	Audio data output.
	Conduit	ls_clk[0]	audio_de[7:0]	Output	Audio data valid output.
	Conduit	audio_clk	audio_metadata[164:0]	Output	Additional information related to 3D audio and multi-stream audio.
	Conduit	audio_clk	audio_format[4:0]	Output	Indicates the audio format detected.
	Conduit	ls_clk[0]	audio_info_ai[47:0]	Output	Audio InfoFrame input bundle.
Auxiliary Memory Interface	Conduit	ls_clk[0]	aux_pkt_addr[6:0]	Output	Auxiliary packet memory buffer address output.
	Conduit	ls_clk[0]	aux_pkt_data[71:0]	Output	Auxiliary packet memory buffer data output.
	Conduit	ls_clk[0]	aux_pkt_wr	Output	Auxiliary packet memory buffer write strobe output.
Auxiliary Control Port	Conduit	ls_clk[0]	gcp[5:0]	Output	General Control Packet output.
	Conduit	ls_clk[0]	info_avi[111:0]	Output	Auxiliary Video Information InfoFrame output.
	Conduit	ls_clk[0]	info_vsi[60:0]	Output	Vendor Specific Information InfoFrame output.
SCDC Control Port	Conduit	scdc_i2c_clk	in_5v_power	Input	Detects the presence of 5V input voltage.
	Conduit	scdc_i2c_clk	in_hpd	Input	Detects the Hot Plug Detect (HPD) status.
Misc.	Conduit	–	version[31:0]	Output	Version of the HDMI core.

5.2.1 Avalon-MM SCDC Management Interface

Table 25. Avalon-MM Status and Control Data Channel (SCDC) Management Interface Signals

The table lists the Avalon Memory-Mapped (Avalon-MM) Status and Control Data Channel (SCDC) Management interface signals.

Signal	Direction	Description
scdc_i2c_clk	Input	Avalon-MM clock input.
scdc_i2c_addr[7:0]	Input	8-bit Avalon-MM address.
scdc_i2c_r	Input	Read signal.
scdc_i2c_rdata[7:0]	Output	Output data.
scdc_i2c_w	Input	Write signal.
scdc_i2c_wdata[7:0]	Input	Input data.

For more information about SCDC, refer to the *HDMI 2.0 Specification Section 10.4 (Status and Control Data Channel)*.

5.2.2 Status and Control Data Channel Interface

For applications using the HDMI 2.0 feature, the HDMI IP core provides a memory slave port to the SCDC registers.

This memory slave port connects to an I^2C slave component. The TMDS_Bit_clock_Ratio output from the SCDC interface indicates when the core requires the 1/40 TMDS bit period to TMDS clock period. This bit is also stored in its corresponding field in the SCDC registers.

The HDMI 2.0 specification requires the core to respond to the presence of the 5V input from the connector and also the state of the HPD signal. The 5V input and HPD signal are used in the register mechanism updates. The signals are synchronous to the scdc_i2c_clk clock domain. You must create a 100-ms delay on the HPD signal externally to the core.

For more information about the Status and Control Data Channel, you may refer to HDMI 2.0 Specification Chapter 10.4.You can obtain the address map for the registers in the HDMI 2.0 specification.

5.3 Sink Clock Tree

The sink core uses different clocks.

The logic clocks the transceiver data into the core using the three CDR clocks: (rx_clk[2:0]).

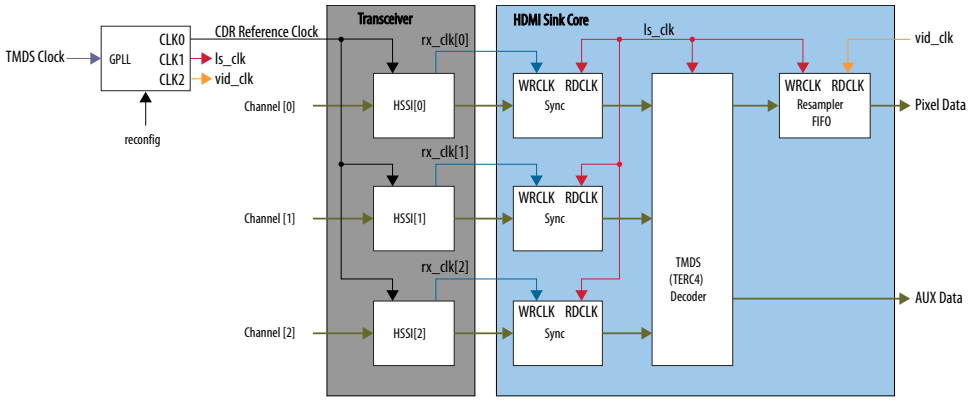
The TMDS and TERC4 decoding is done at the link-speed clock (ls_clk). The sink then resamples the pixel data and presents the data at the output of the core at the video pixel clock (vid_clk).

The pixel data clock depends on the video format used (within HDMI specification).

For HDMI sink, you need to instantiate 3 receiver channels to receive data.

Figure 34. Sink Clock Tree

The figure shows how the different clocks can be selected for the sink core.



Related Links

HDMI Hardware Demonstration on page 52
For more information about the transmitter and receiver channels.

6 HDMI Parameters

Use the settings in the HDMI parameter editor to configure your design.

6.1 HDMI Source Parameters

Table 26. HDMI Source Parameters

Parameter	Value	Description
Device family	Stratix V Arria V Arria 10	Targeted device family; matches the project device family.
Direction	Transmitter = Source Receiver = Sink	Select HDMI source.
Symbols per clock	1, 2, or 4 symbols per clock	Determines how many TMDS symbols and pixels are processed per clock. • Stratix V supports 1 or 2 symbols per clock • Arria V supports 1, 2, or 4 symbols per clock • Arria 10 supports only 2 symbols per clock
Support auxiliary	0 = No AUX 1 = AUX	Determines if auxiliary channel encoding is included.
Support deep color	0 = No deep color 1 = Deep color	Determines if the core can encode deep color formats. To enable this parameter, you must also enable the **Support auxiliary** parameter.
Support audio	0 = No audio 1 = Audio	Determines if the core can encode audio data. To enable this parameter, you must also enable the **Support auxiliary** parameter.

6.2 HDMI Sink Parameters

Table 27. HDMI Sink Parameters

Parameter	Value	Description
Device family	Stratix V Arria V Arria 10	Targeted device family; matches the project device family.
Direction	Transmitter = Source Receiver = Sink	Select HDMI sink.
Symbols per clock	1, 2, or 4 symbols per clock	Determines how many TMDS symbols and pixels are processed per clock.

continued...

Parameter	Value	Description
		• Stratix V supports 1 or 2 symbols per clock • Arria V supports 1, 2, or 4 symbols per clock • Arria 10 supports only 2 symbols per clock
Support auxiliary	0 = No AUX 1 = AUX	Determines if auxiliary channel encoding is included.
Support deep color	0 = No deep color 1 = Deep color	Determines if the core can encode deep color formats. To enable this parameter, you must also enable the **Support auxiliary** parameter.
Support audio	0 = No audio 1 = Audio	Determines if the core can encode audio data. To enable this parameter, you must also enable the **Support auxiliary** parameter.
Manufacturer OUI	—	The Manufacturer Organizationally Unique Identifier (OUI) assigned to the manufactured device to be written into the SCDC registers of address 0xD0, 0xD1, and 0xD2. Key in 3 byte hexadecimal data.
Device ID String	—	The Device Identification (ID) string to be written into the SCDC registers from addresses 0xD3 to 0xDa. Use this parameter to identify the sink device. You can key in up to eight ASCII characters. If you use less than eight characters, the unused bytes are set to 0x00.
Hardware Revision	—	Indicates the major and minor revisions of the hardware. Key in one byte of integer data. • Upper byte represents major revision. • Lower byte represents minor revision. The hardware major revision increments on a major silicon or board revision. The hardware minor revision increments on a minor silicon revision or minor board revision and resets to 0 when the major revision increments.

6.3 HDMI Design Example Parameters

Table 28. HDMI Design Example Parameters

These options are available for Arria 10 devices only.

Parameter	Value	Description
Available Design Example		
Select Design	None, Arria 10 HDMI RX-TX Retransmit	Select the design example to be generated. • None: No design example is available for the current parameter selection • Arria 10 HDMI RX-TX Retransmit: The generated design example which has preconfigured parameter settings—does not follow user settings.

Design Example Files		
Simulation	On, Off	Turn on this option to generate the necessary files for the simulation testbench.
Synthesis	On, Off	Turn on this option to generate the necessary files for Quartus Prime compilation and hardware demonstration.

Generated HDL Format		
Generate File Format	Verilog, VHDL	Select your preferred HDL format for the generated design example fileset. *Note:* This option only determines the format for the generated top level IP files. All other files (e.g. example testbenches and top level files for hardware demonstration) are in Verilog HDL format.

Target Development Kit		
Select Board	No Development Kit, Arria 10 GX FPGA Development Kit, Custom Development Kit	Select the board for the targeted design example. • No Development Kit: This option excludes all hardware aspects for the design example. The IP core sets all pin assignments to virtual pins. • Arria 10 GX FPGA Development Kit: This option automatically selects the project's target device to match the device on this development kit. You may change the target device using the **Change Target Device** parameter if your board revision has a different device variant. The IP core sets all pin assignments according to the development kit. • Custom Development Kit: This option allows the design example to be tested on a third party development kit with an Intel FPGA. You may need to set the pin assignments on your own.

Target Device		
Change Target Device	On, Off	Turn on this option and select the preferred device variant for the development kit.

7 HDMI Hardware Demonstration

The High-Definition Multimedia Interface (HDMI) hardware demonstration helps you evaluate the functionality of the HDMI IP core and provides a starting point for you to create your own design.

The demonstration runs on the following device kits:

- Arria V GX starter kit
- Stratix V GX development kit

Related Links

AN 745: Design Guidelines for DisplayPort and HDMI Interfaces

7.1 Hardware Demonstration Components

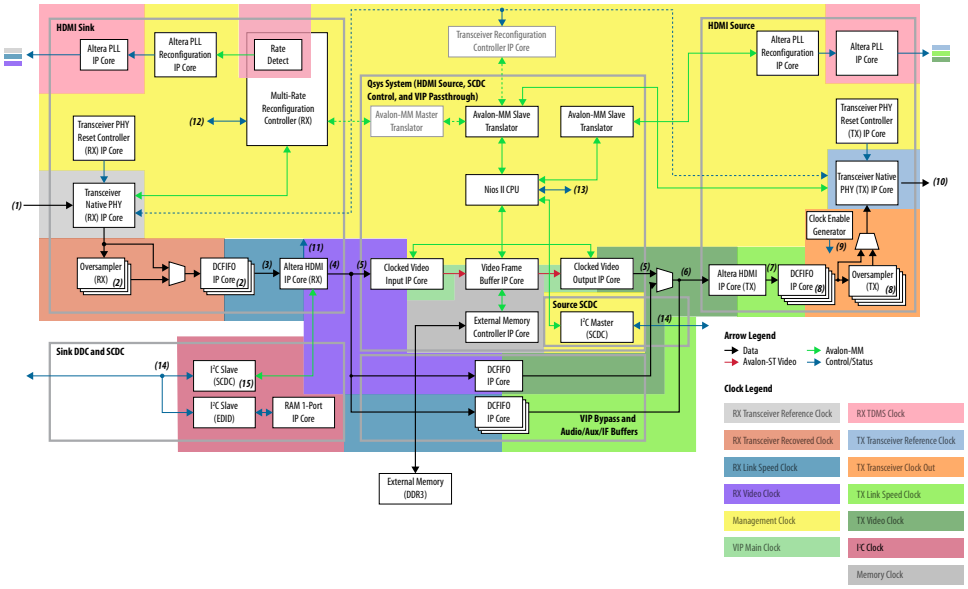
The demonstration designs instantiate the Video and Image Processing (VIP) Suite IP cores or FIFO buffers to perform a direct HDMI video stream passthrough between the HDMI sink and source.

The hardware demonstration design comprises the following components:

- HDMI sink
  - Transceiver Native PHY (RX)
  - Transceiver PHY Reset Controller (RX)
  - Altera PLL
  - Altera PLL Reconfiguration
  - Multirate Reconfiguration Controller (RX)
  - Oversampler (RX)
  - DCFIFO
- Sink Display Data Channel (DDC) and Status and Control Data Channel (SCDC)
- Transceiver Reconfiguration Controller
- VIP bypass and audio, auxiliary and infoframe buffers
- Qsys system
  - VIP passthrough for HDMI video stream
  - Source SCDC controller
  - HDMI source reconfiguration controller
- HDMI source
  - Transceiver Native PHY (TX)
  - Transceiver fPLL
  - Transceiver PHY Reset Controller (TX)
  - Altera PLL
  - Altera PLL Reconfiguration
  - Oversampler (TX)
  - DCFIFO
  - Clock Enable Generator

Figure 35. HDMI Hardware Demonstration Block Diagram

The figure below shows a high level architecture of the design.



The following details of the example design architecture correspond to the numbers in the block diagram.

1. The sink TMDS data has three channels: data channel 0 (blue), data channel 1 (green), and data channel 2 (red).
2. The Oversampler (RX) and dual-clock FIFO (DCFIFO) instances are duplicated for each TMDS data channel (0,1,2).
3. The video data input width for each color channel of the HDMI RX core is equivalent to RX transceiver PCS-PLD parallel data width per channel.
4. Each color channel is fixed at 16 bits per color. The video data output width of the HDMI RX core is equivalent to the value of symbols per clock*16*3.
5. The video data input width of the Clocked Video Input (CVI) and Clocked Video Output (CVO) IP cores are equivalent to the value of NUMBER_OF_PIXELS_IN_PARALLEL * BITS_PER_PIXEL_PER_COLOR_PLANE * NUMBER_OF_COLOR_PLANES. To interface with the HDMI core, the values of NUMBER_OF_PIXELS_IN_PARALLEL, BITS_PER_PIXEL_PER_COLOR_PLANE, and NUMBER_OF_COLOR_PLANES must match the symbols per clock, 16 and 3 respectively.
6. The video data input width of the HDMI TX core is equivalent to the value of symbols per clock*16*3. You can use the user switch to select the video data from the CVO IP core (VIP passthrough) or DCFIFO (VIP bypass).
7. The video data output width for each color channel of the HDMI TX core is equivalent to TX transceiver PCS-PLD parallel data width per channel.
8. The DCFIFO and the Oversampler (TX) instances are duplicated for each TMDS data channel (0,1,2) and clock channel.
9. The Oversampler (TX) uses the clock enable signal to read data from the DCFIFO.
10. The source TMDS data has four channels: data channel 0 (blue), data channel 1 (green), data channel 2 (red), and clock channel.

11. The RX Multi-rate Reconfiguration Controller requires the status of `TMDS_Bit_clock_ Ratio` port to perform appropriate RX reconfiguration between the TMDS character rates below 340 Mcsc (HDMI 1.4b) and above 340 Mcsc (HDMI 2.0). The status of the port is also required by the Nios II processor and the HDMI TX core to perform appropriate TX reconfiguration and scrambling.
12. The reset control and lock status signals from HDMI PLL, RX Transceiver Reset Controller and HDMI RX core.
13. The reset and oversampling control signals for HDMI PLL, TX Transceiver Reset Controller, and HDMI TX core. The lock status and rate detection measure valid signals from the HDMI sink initiate the TX reconfiguration process.
14. The I^2C SCL and SDA lines with tristate buffer for bidirectional configuration. Use the ALTIOBUF IP core for Arria V and Stratix V devices.
15. The SCDC is mainly designed for the source to update the `TMDS_Bit_Clock_Ratio` and `Scrambler_Enable` bits of the sink TMDS Configuration register. The HDMI RX core does not support SCDC read request feature for this release.

7.1.1 Transceiver Native PHY (RX)

- Transceiver Native PHY in Arria V devices
  - To operate the TMDS bit rate up to 3,400 Mbps, configure the Transceiver Native PHY at 20 bits at PCS – PLD interface with the HDMI RX core at 2 symbols per clock. When the PCS – PLD interface width is 20 bits, the minimum link rate is 611 Mbps.
  - To operate the TMDS bit rate up to 6,000 Mbps, configure the Transceiver Native PHY at 40 bits with the HDMI RX core at 4 symbols per clock. When the PCS – PLD interface width is 40 bits, the minimum link rate is 1,000 Mbps.
  - Oversampling is required for TMDS bit rate which is below the minimum link rate.
- Transceiver Native PHY in Stratix V devices
  - To operate the TMDS bit rate up to 6,000 Mbps, configure the Transceiver Native PHY at 20 bits at PCS – PLD interface with the HDMI RX core at 2 symbols per clock. When the PCS – PLD interface width is 20 bits, the minimum link rate is 611 Mbps.

Table 29. Arria V and Stratix V Transceiver Native PHY (RX) Configuration Settings (6,000 Mbps)

This table shows an example of Arria V and Stratix V Transceiver Native PHY (RX) configuration settings for TMDS bit rate of 6,000 Mbps.

Parameters	Settings
Datapath Options	
Enable TX datapath	Off
Enable RX datapath	On
Enable Standard PCS	On
Initial PCS datapath selection	Standard
Number of data channels	3
Enable simplified data interface	On

RX PMA	
Data rate	6,000 Mbps
Enable CDR dynamic reconfiguration	On
Number of CDR reference clocks	2 [2]
Selected CDR reference clock	0 [2]
Selected CDR reference clock frequency	600 MHz
PPM detector threshold	1,000 PPM
Enable rx_pma_clkout port	On
Enable rx_is_lockedtodata port	On
Enable rx_is_lockedtoref port	On
Enable rx_set_locktodata and rx_set_locktoref ports	On

Standard PCS	
Standard PCS protocol	Basic
Standard PCS/PMA interface width	• 10 (for 1 symbol per clock) • 20 (for 2 and 4 symbols per clock)
Enable RX byte deserializer	• Off (for 1 and 2 symbols per clock) • On (for 4 symbols per clock)

2 The Bitec HDMI 2.0 HSMC daughter card routes the TMDS clock pin to the transceiver serial data pin. To use the TMDS clock to drive the HDMI PLL, the TMDS clock must also drive the transceiver dedicated reference clock pin. The number of CDR reference clocks is 2 with reference clock 1 (unused) driven by the TMDS clock and reference clock 0 driven by the HDMI PLL output clock. The selected CDR reference clock will be fixed at 0.

Table 30. Arria V and Stratix V Transceiver Native PHY (RX) Common Interface Ports

This table describes the Arria V and Stratix V Transceiver Native PHY (RX) common interface ports.

Signals	Direction	Description
Clocks		
rx_cdr_refclk[1:0]	Input	Input reference clock for the RX CDR circuitry. • To support arbitrary wide data rate range from 250 Mbps to 6,000 Mbps, you need a generic core PLL to obtain a higher clock frequency from the TMDS clock. You need a higher clock frequency to create oversampled stream for data rates below the minimum transceiver data rate—for example, 611 Mbps or 1,000 Mbps). • If the TMDS clock pin is routed to the transceiver dedicated reference clock pin, you only need to create one transceiver reference clock input. You can use the TMDS clock as reference clock for a generic core PLL to drive the transceiver. • If you use Bitec HDMI 2.0 HSMC daughter card, the TMDS clock pin is routed to the transceiver serial data pin. In this case, to use the TMDS clock as a reference clock for a generic core PLL, the clock must also drive the transceiver dedicated reference clock. Connect bit 0 to the generic core PLL output and bit 1 to the TMDS clock and set the selected CDR reference clock at 0.
rx_std_clkout[2:0]	Output	RX parallel clock output. • The CDR circuitry recovers the RX parallel clock from the RX data stream when the CDR is configured at lock-to-data mode. • The RX parallel clock is a mirror of the CDR reference clock when the CDR is configured at lock-to-reference mode.
rx_std_coreclkin[2:0]	Input	RX parallel clock that drives the read side of the RX phase compensation FIFO. Connect to rx_std_clkout ports.
rx_pma_clkout[2:0]	Output	RX parallel clock (recovered clock) output from PMA. Leave unconnected.
Resets		
rx_analogreset[2:0]	Input	Active-high, edge-sensitive, asynchronous reset signal. When asserted, resets the RX CDR circuit, deserializer. Connect to Transceiver PHY Reset Controller IP core.
rx_digitalreset[2:0]	Input	Active-high, edge-sensitive, asynchronous reset signal. When asserted, resets the digital component of the RX data path. Connect to the Transceiver PHY Reset Controller IP core.
PMA Ports		
rx_set_locktoref[2:0]	Input	When asserted, programs the RX CDR to lock to reference mode manually. The lock to reference mode enables you to control the reset sequence using rx_set_locktoref and rx_set_locktodata. The Multirate Reconfiguration Controller (RX) sets this port to 1 if oversampling mode is required. Otherwise, this port is set to 0.

continued...

PMA Ports		
		Refer "Transceiver Reset Sequence" in Transceiver Reset Control in Arria V/Stratix V Devices for more information about manual control of the reset sequence.
rx_set_locktodata[2:0]	Input	Always driven to 0. When rx_set_locktoref is driven to 1, the CDR is configured to lock-to-reference mode. Otherwise, the CDR is configured to lock-to-data mode.
rx_is_lockedtoref[2:0]	Output	When asserted, the CDR is locked to the incoming reference clock. Connect this port to rx_is_lockedtodata port of the Transceiver PHY Reset Controller IP core when rx_set_locktoref is 1.
rx_is_lockedtodata[2:0]	Output	When asserted, the CDR is locked to the incoming data. Connect this port to rx_is_lockedtodata port of Transceiver PHY Reset Controller IP core when rx_set_locktoref is 0.
rx_serial_data[2:0]	Input	RX differential serial input data.

PCS Ports		
unused_rx_parallel_data	Output	Leave unconnected.
rx_parallel_data[S*3*10-1:0]	Output	PCS RX parallel data. *Note:* S=Symbols per clock.

Calibration Status Port		
rx_cal_busy[2:0]	Output	When asserted, indicates that the initial RX calibration is in progress. This port is also asserted if the reconfiguration controller is reset. Connect to the Transceiver PHY Reset Controller IP core.

Reconfiguration Ports		
reconfig_to_xcvr[209:0]	Input	Reconfiguration signals from the Transceiver Reconfiguration Controller.
reconfig_from_xcvr[137:0]	Output	Reconfiguration signals to the Transceiver Reconfiguration Controller.

7.1.2 Altera PLL IP Cores

Use the Altera PLL IP core as the HDMI PLL to generate reference clock for RX or TX transceiver, link speed, and video clocks for the HDMI RX or TX IP core.

The HDMI PLL is referenced by the arbitrary TMDS clock. For HDMI source, you can reference the HDMI PLL by a separate clock source in the VIP passthrough design, which contains frame buffer. The HDMI PLL for TX has the same desired output frequencies as RX across symbols per clock and color depth.

- For TMDS bit rates ranging from 3,400 Mbps to 6,000 Mbps (HDMI 2.0), the TMDS clock rate is 1/40 of the TMDS bit rate. The HDMI PLL generates reference clock for RX/TX transceiver at 4 times the TMDS clock.
- For TMDS bit rates below 3,400 Mbps (HDMI 1.4b), the TMDS clock rate is 1/10 of the TMDS bit rate. The HDMI PLL generates reference clock for RX/TX transceiver at identical rate as the TMDS clock.

If the TMDS link operates at TMDS bit rates below the minimum RX/TX transceiver link rate, your design requires oversampling and a factor of 5 is chosen. The minimum link rate of the RX/TX transceiver vary across device families and symbols per clock. The HDMI PLL generates reference clock for RX/TX transceiver at 5 times the TMDS clock.

Note: Place the Altera PLL in the transmit path (`pll_hdmi_tx`) in the physical location next to the transceiver PLL.

Table 31. HDMI PLL Desired Output Frequencies for 8-bpc Video

This table shows an example of HDMI PLL desired output frequencies across various TMDS clock rates and symbols per clock for all supported device families using 8-bpc video.

Device Family	Symbols Per Clock	Minimum Link Rate (Mbps)	TMDS Bit Rate (Mbps)	Oversampling (5x) Required	TMDS Clock Rate (MHz)	RX/TX Transceiver Refclk (MHz)	RX/TX Link Speed Clock (MHz)	RX/TX Video Clock (MHz)
Arria V	2	611	270	Yes	27	135	13.5	13.5
			742.5	No	74.25	74.25	37.125	37.125
			1,485	No	148.5	148.5	74.25	74.25
			2,970	No	297	297	148.5	148.5
	4	1,000	270	Yes	27	135	6.75	6.75
			742.5	Yes	74.25	371.25	18.5625	18.5625
			1,485	No	148.5	148.5	37.125	37.125
			5,940	No	148.5	594	148.5	148.5
Stratix V	2	611	540	Yes	54	270	27	27
			1,620	No	162	162	81	81
			5,934	No	296.7	593.4	296.7	296.7

The color depths greater than 8 bpc or 24 bpp are defined to be deep color. For a color depth of 8 bpc, the core carries the pixels at a rate of one pixel per TMDS clock. At deeper color depths, the TMDS clock runs faster than the source pixel clock to provide the extra bandwidth for the additional bits.

The TMDS clock rate is increased by the ratio of the pixel size to 8 bits:

- 8 bits mode—TMDS clock = 1.0 × pixel or video clock (1:1)
- 10 bits mode—TMDS clock = 1.25 × pixel or video clock (5:4)
- 12 bits mode—TMDS clock = 1.5 × pixel or video clock (3:2)
- 16 bits mode—TMDS clock = 2 × pixel or video clock (2:1)

Table 32. HDMI PLL Desired Output Frequencies for Deep Color Video

This table shows an example of HDMI PLL desired output frequencies across symbols per clock and color depths.

Symbols Per Clock	Oversampling (5x) Required	Bits per color	TMDS Bit Rate (Mbps)	TMDS Clock Rate (MHz)	RX/TX Transceiver Refclk (MHz)	RX/TX Link Speed Clock (MHz)	RX/TX Video Clock (MHz)
2	Yes	8	270	27	135	13.5	13.5
		10 [3]	337.5	33.75	168.75	16.875	13.5
		12 [3]	405	40.5	202.5	20.25	13.5
		16 [3]	540	54	270	27	13.5
4	No	8	1,485	148.5	148.5	37.125	37.125
		10 [3]	1,856.25	185.625	185.625	46.40625	37.125
		12 [3]	2,227.5	222.75	222.75	55.6875	37.125
		16 [3]	2,970	297	297	74.25	37.125

The default frequency setting of the HDMI PLL is fixed at possible maximum value for each clock for appropriate timing analysis.

Note: This default combination is not valid for any HDMI resolution. The core will reconfigure to the appropriate settings upon power up.

7.1.3 Altera PLL Reconfig IP Core

The Altera PLL Reconfig IP core facilitates dynamic real-time reconfiguration of PLLs in Intel FPGAs.

Use the IP core to update the output clock frequency, PLL bandwidth in real-time, without reconfiguring the entire FPGA.

You can run this IP core at 100 MHz in Arria 10 and Stratix V devices. In Arria V devices, you need to run at 75 MHz for timing closure. To simplify clocking in Arria V devices, the entire management clock domain is capped at 75 MHz.

7.1.4 Multirate Reconfig Controller (RX)

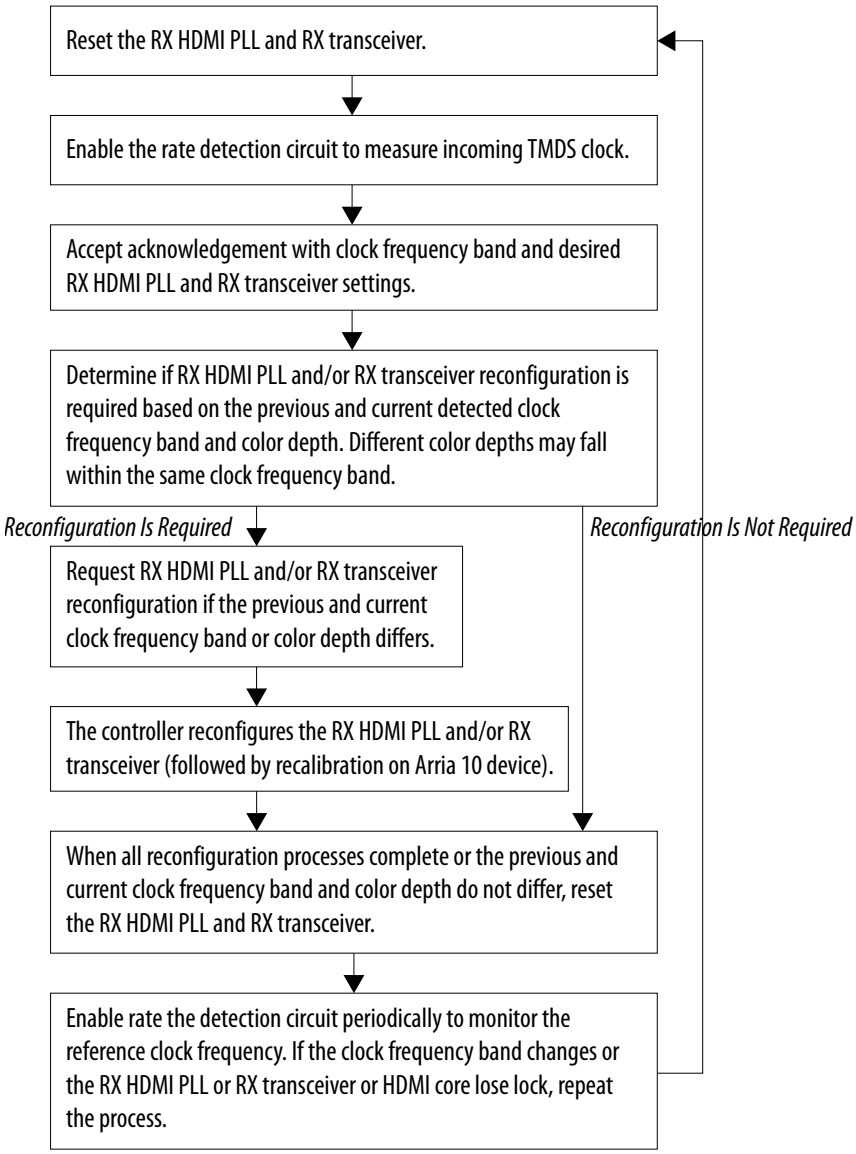
The Multirate Reconfig Controller implements rate detection circuitry with the HDMI PLL to drive the RX transceiver to operate at any arbitrary link rates ranging from 250 Mbps to 6,000 Mbps. Link rate of 6,000 Mbps is not the absolute maximum but the intention is to support HDMI 2.0 link rate.

The Multirate Reconfig Controller performs rate detection on the HDMI PLL arbitrary reference clock, which is also the TMDS clock, to determine the clock frequency band. Based on the detected clock frequency band, the circuitry dynamically reconfigures the HDMI PLL and transceiver settings to accommodate for the link rate change.

3 For this release, deep color video is only demonstrated in VIP bypass mode. It is not available in VIP passthrough mode.

Figure 36. Multirate Reconfiguration Sequence Flow

This figure illustrates the multirate reconfiguration sequence flow of the controller when it receives input data stream and reference clock frequency, or when the tranceiver is unlocked.



7.1.5 Oversampler (RX)

The Oversampler (RX) extracts data from the oversampled incoming data stream when the detected clock frequency band is below the transceiver minimum link rate.

The oversampling factor is fixed at 5 and you can program the data width to support different number of symbols. The supported data width is 20 bit for 2 symbols per clock and 40 bits for 4 symbols per clock. The extracted bit will be accompanied by data valid pulse which asserts every 5 clock cycles.

7.1.6 DCFIFO

The DCFIFO transfers data from the RX transceiver recovered clock domain to the RX link speed clock domain. The DCFIFO transfers data from the TX link speed clock domain to the TX transceiver parallel clock out domain.

- Sink
  - When the Multirate Reconfig Controller (RX) detects an incoming input stream that is below the transceiver minimum link rate, the DCFIFO accepts the data from the Oversampler with data valid pulse as write request asserted every 5 clock cycles.
  - Otherwise, it accepts data directly from the transceiver with write request asserted at all times.
- Source
  - When Nios II processor determines the outgoing data stream is below the TX transceiver minimum link rate, the TX transceiver accepts the data from the Oversampler (TX).
  - Otherwise, the TX transceiver reads data directly from the DCFIFO with read request asserted at all times.

7.1.7 Sink Display Data Channel (DDC) & Status and Control Data Channel (SCDC)

The HDMI source uses the DDC to determine the capabilities and characteristics of the sink by reading the Enhanced Extended Display Identification Data (E-EDID) data structure.

The E-EDID memory is stored using the RAM 1-Port IP core. A standard two-wire (clock and data) serial data bus protocol (I2C slave-only controller) is used to transfer CEA-861-D compliant E-EDID data structure.

The 8-bit I^2C slave addresses for the E-EDID are 0xA0/0xA1. The LSB indicates the access type: 1 for read and 0 for write. When an HPD event occurs, the I^2C slave responds to E-EDID data by reading from the RAM.

The I^2C slave-only controller is also used to support SCDC for HDMI 2.0 operation. The 8-bit I^2C slave addresses for the SCDC are 0xA8/0xA9. When an HPD event occurs, the I^2C slave performs write/read transaction to/from SCDC interface of HDMI RX core. This I^2C slave-only controller for SCDC is not required if HDMI 2.0 is not intended.

7.1.8 Transceiver Reconfiguration Controller

You can use the Transceiver Reconfiguration Controller IP core to change the device transceiver settings at any time.

You can selectively reconfigure any portion of the transceiver. The reconfiguration of each portion requires a read-modify-write operation (read first, then write). The read-modify-write operation modifies only the appropriate bits in a register and does not affect the other bits.

The Transceiver Reconfiguration Controller is only available and required in Arria V and Stratix V devices. Because the RX and TX transceivers share a single controller, the controller requires Qsys interconnects, such as Avalon-MM Master Translator and Avalon-MM Slave Translator, in the Qsys system.

- The Avalon-MM Master Translator provides an interface between this controller and the RX Multirate Reconfig Controller.
- The Avalon-MM Slave Translator arbitrates the RX and TX reconfiguration event for this controller.

In Arria 10 devices, the Transceiver Native PHY has a direct access the Avalon-MM reconfiguration interface.

- The RX Multirate Reconfig Controller directly drives the RX transceiver reconfiguration interface.
- The Avalon-MM Slave Translator converts the Nios II reconfiguration command and directly drives the TX transceiver reconfiguration interface.

7.1.9 VIP Bypass and Audio, Auxiliary and InfoFrame Buffers

The video data output and synchronization signals from HDMI RX core is looped through a DCFIFO across RX and TX video clock domains. The General Control Packet (GCP), InfoFrames (AVI, VSI, and AI), auxiliary data and audio data are looped through DCFIFOs across RX and TX link speed clock domains.

The auxiliary data port of the HDMI TX core controls the auxiliary data that flow through DCFIFO through backpressure. The backpressure ensures there is no incomplete auxiliary packet on the auxiliary data port. This block also performs external filtering on the audio data and audio clock regeneration packet from the auxiliary data stream before sending to the HDMI TX core auxiliary data port.

7.1.10 Transceiver Native PHY (TX)

The Arria V and Stratix V Transceiver Native PHY (TX) configuration settings are typically the same as RX.

Table 33. Arria V and Stratix V Transceiver Native PHY (TX) Configuration Settings (6,000 Mbps)

This table shows an example of Arria V and Stratix V Transceiver Native PHY (TX) configuration settings for TMDS bit rate of 6,000 Mbps.

Parameters	Settings
Datapath Options	
Enable TX datapath	On
Enable RX datapath	Off
Enable Standard PCS	On
Initial PCS datapath selection	Standard
Number of data channels	4
Bonding mode	xN
Enable simplified data interface	On

TX PMA	
Data rate	6,000 Mbps
TX local clock division factor	1
Enable TX PLL dynamic reconfiguration	On
Use external TX PLL	Off
Number of TX PLLs	1
Main TX PLL logical index	0
Number of TX PLL reference clocks	1
PLL type	CMU
Reference clock frequency	600 MHz
Selected reference clock source	0
Selected clock network	xN

Standard PCS	
Standard PCS protocol	Basic
Standard PCS/PMA interface width	• 10 (for 1 symbol per clock) • 20 (for 2 and 4 symbols per clock)
Enable TX byte serializer	• Off (for 1 and 2 symbols per clock) • On (for 4 symbols per clock)

Table 34. Arria V and Stratix V Transceiver Native PHY (TX) Common Interface Ports

This table describes the Arria V and Stratix V Transceiver Native PHY (TX) common interface ports.

Signals	Direction	Description
Clocks		
`tx_pll_refclk`	Input	The reference clock input to the TX PLL.
`tx_std_clkout[3:0]`	Output	TX parallel clock output.
`tx_std_coreclkin[3:0]`	Input	TX parallel clock that drives the write side of the TX phase compensation FIFO. Connect to `tx_std_clkout[0]` ports.
Resets		
`tx_analogreset[3:0]`	Input	When asserted, resets all the blocks in TX PMA. Connect to Transceiver PHY Reset Controller (TX) IP core.
`tx_digitalreset[3:0]`	Input	When asserted, resets all the blocks in TX PCS. Connect to the Transceiver PHY Reset Controller (TX) IP core.
TX PLL		
`pll_powerdown`	Input	When asserted, resets the TX PLL. Connect to the Transceiver PHY Reset Controller (TX) IP core.
`pll_locked`	Output	When asserted, indicates that the TX PLL is locked. Connect to the Transceiver PHY Reset Controller (TX) IP core.

PCS Ports		
unused_tx_parallel_data	Input	Leave unconnected.
tx_parallel_data[S*4*10-1:0]	Input	PCS TX parallel data. *Note:* S=Symbols per clock.

PMA Port		
tx_serial_data[3:0]	Output	TX differential serial output data.

Calibration Status Port		
tx_cal_busy[3:0]	Output	When asserted, indicates that the initial TX calibration is in progress. This port is also asserted if the reconfiguration controller is reset. Connect to the Transceiver PHY Reset Controller (TX) IP core.

Reconfiguration Ports		
reconfig_to_xcvr[349:0]	Input	Reconfiguration signals from the Transceiver Reconfiguration Controller.
reconfig_from_xcvr[229:0]	Output	Reconfiguration signals to the Transceiver Reconfiguration Controller.

7.1.11 Transceiver PHY Reset Controller

The Transceiver PHY Reset Controller IP core ensures a reliable initialization of the RX and TX transceivers.

The reset controller has separate reset controls per channel to handle synchronization of reset inputs, lagging of PLL locked status, and automatic or manual reset recovery mode.

7.1.12 Oversampler (TX)

The Oversampler (TX) transmits data by repeating each bit of the input word a given number of times and constructs the output words.

The oversampling factor is fixed at 5. The Oversampler (TX) assumes that the input word is only valid every 5 clock cycles. This block enables when the outgoing data stream is determined to be below the TX transceiver minimum link rate by reading once from the DCFIFO every 5 clock cycles.

7.1.13 Clock Enable Generator

The Clock Enable Generator is a logic that generates a clock enable pulse.

This clock enable pulse asserts every 5 clock cycles and serves as a read request signal to clock the data out from DCFIFO.

7.1.14 Qsys System

The Qsys system consists of the VIP passthrough for HDMI video stream, source SDC controller, and source reconfiguration controller blocks.

7.1.14.1 VIP Passthrough for HDMI Video Stream

For certain example designs, you can loop the video data output and synchronization signals from HDMI RX core through the VIP data path.

The Clocked Video Input II (CVI II) IP core converts clocked video formats to Avalon-ST video by stripping incoming clocked video of horizontal and vertical blanking, leaving only active picture data.

- The IP core provides clock crossing capabilities to allow video formats running at different frequencies to enter the system.
- The IP core also detects the format of the incoming clocked video and provides this information in a set of registers.
- The Nios II processor uses this information to reconfigure the video frame mode registers of the CVO IP core in the VIP passthrough design.

The Video Frame Buffer II IP core buffers video frames into external RAM.

- The IP core supports double and triple buffering with a range of options for frame dropping and repeating.
- You can use the buffering options to solve throughput issues in the data path and perform simple frame rate conversion.

In a VIP passthrough design, you can reference the HDMI source PLL and sink PLL using separate clock sources. However, in a VIP bypass design, you must reference the HDMI source PLL and sink PLL using the same clock source.

The Clocked Video Output II (CVO II) IP core converts data from the flow-controlled Avalon-ST video protocol to clocked video.

- The IP core provides clock crossing capabilities to allow video formats running at different frequencies to be created from the system.
- It formats the Avalon-ST video into clocked video by inserting horizontal and vertical blanking and generating horizontal and vertical synchronization information using the Avalon-ST video control and active picture packets.
- The video frame is described using the mode registers that are accessed through the Avalon-MM control port.

Table 35. Difference between VIP Passthrough Design and VIP Bypass Design

VIP Passthrough Design	VIP Bypass Design
• Can reference the HDMI source PLL and sink PLL using separate clock sources • Demonstrates only certain video formats—640×480p60, 720×480p60, 1280×720p60, 1920×1080p60, and 3840×2160p24	• Must reference the HDMI source PLL and sink PLL using the same clock source • Demonstrates all video formats.

Table 36. VIP Passthrough and VIP Bypass Options for the Supported Devices

Device Family	Symbols Per Clock	HDMI Specification Support	Bitec HDMI 2.0 Daughter Card	Directory	VIP Passthrough	VIP Bypass
Arria V	2	1.4b	HSMC (Rev8)	av_sk	Supported	Supported
Arria V	4	2.0	HSMC (Rev8)	av_sk_hdmi2	Not supported	Supported
Stratix V	2	2.0	HSMC (Rev8)	sv_hdmi2	Not supported	Supported

7.1.14.2 Source SCDC Controller

The source SCDC Controller contains the I^2C master controller. The I^2C master controller transfers the SCDC data structure from the FPGA source to the external sink for HDMI 2.0 operation.

For example, if the outgoing data stream is 6,000 Mbps, the Nios II processor commands the I^2C master controller to update the `TMDS_Bit_Clock_Ratio` and `Scrambler_Enable` bits of the sink TMDS configuration register to 1. The same I^2C master can also transfer the DDC data structure (E-EDID) between the HDMI source and external sink.

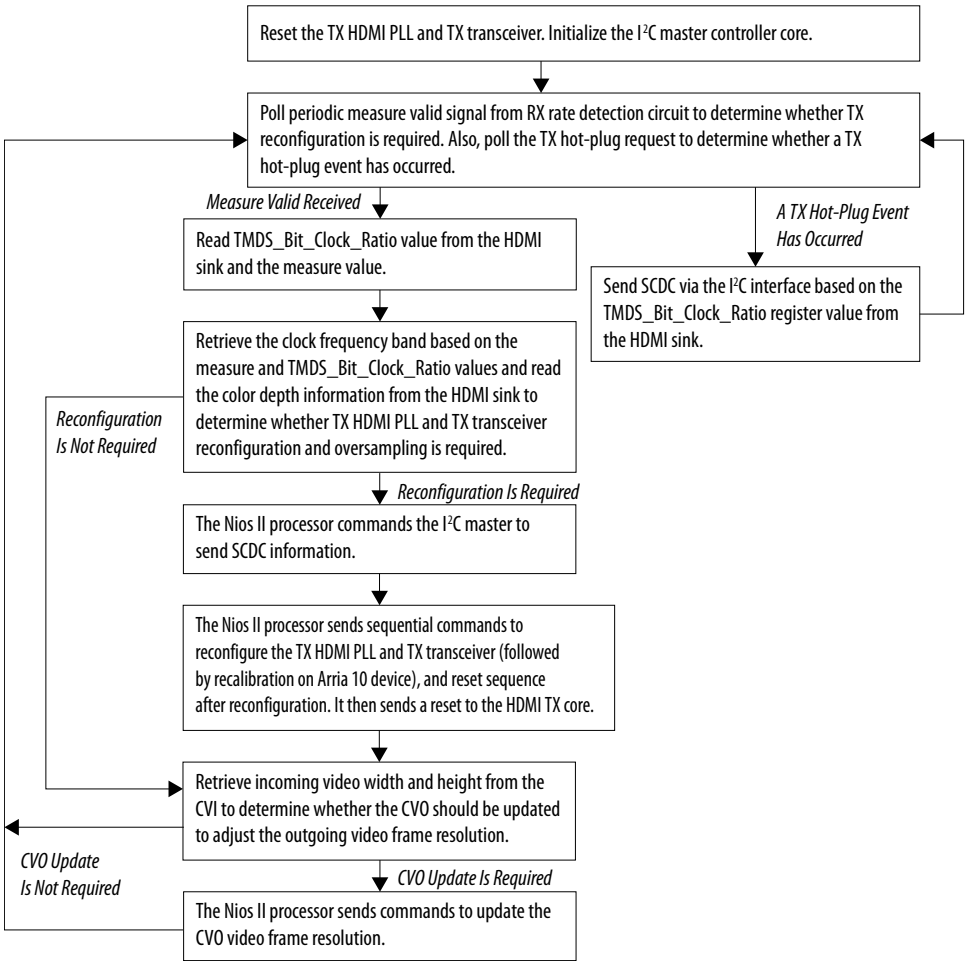
7.1.14.3 Source Reconfiguration Controller

The Nios II CPU acts as the multirate reconfiguration controller for the HDMI source.

The CPU relies on the periodic rate detection from the Multirate Reconfig Controller (RX) to determine if TX requires reconfiguration. The Avalon-MM slave translator provides the interface between the Nios II processor Avalon-MM master interface and the Avalon-MM slave interfaces of the externally instantiated HDMI source's Altera PLL Reconfig IP core and Transceiver Native PHY (TX).

Figure 37. Nios II Software Flow

The reconfiguration sequence flow for TX is the same as RX, except that the PLL and transceiver reconfiguration, and the reset sequence is performed sequentially. The figure illustrates the Nios II software flow that involves the controls for CVO, I²C master and HDMI source.



7.2 HDMI Hardware Demonstration Requirements

The HDMI demonstration requires an Intel FPGA board and supporting hardware.

- Intel FPGA board
- Bitec HDMI 2.0 daughter card
- Standard HDMI source—for example, PC with a graphic card and HDMI output
- Standard HDMI sink—for example, monitor with HDMI input
- 2 HDMI cables
  - A cable to connect the graphics card to the Bitec daughter card RX connector.
  - A cable to connect the Bitec daughter card TX connector to the monitor.

Table 37. Intel FPGA Boards and Bitec HDMI 2.0 Daughter Cards Supported for the Demonstration

Example Design	Intel FPGA Board	Bitec HDMI 2.0 Daughter Card
Arria V (av_sk)	Arria V GX FPGA Starter Kit	HSMC (Rev8)
Arria V (av_sk_hdmi2)	Arria V GX FPGA Starter Kit	HSMC (Rev8)
Stratix V (sv_hdmi2)	Stratix V GX FPGA Development Kit	HSMC (Rev8)

Related Links

- Arria V GX Starter Kit User Guide
- Stratix V GX FPGA Development Kit User Guide

7.3 Demonstration Walkthrough

Setting up and running the HDMI hardware demonstration consists of four stages.

You can use the Intel-provided scripts to automate these stages.

1. Set up the hardware.
2. Copy the design files to your working directory.
3. Build and compile the design.
4. View the results.

7.3.1 Set Up the Hardware

The first stage of the demonstration is to set up the hardware.

To set up the hardware for the demonstration:

1. Connect the Bitec HDMI 2.0 daughter card to the FPGA development board.
2. Connect the FPGA board to your PC using a USB cable.

   Note: The Arria V GX FPGA Starter Kit and Stratix V GX FPGA Development Kit have an On-Board Intel® FPGA Download Cable II connector. If your version of the board does not have this connector, you can use an external Intel FPGA Download Cable cable.
3. Connect an HDMI cable from the HDMI RX connector on the Bitec HDMI 2.0 daughter card to a standard HDMI source, in this case a PC with a graphic card and HDMI output.
4. Connect another HDMI cable from the HDMI TX connector on the Bitec HDMI 2.0 daughter card to a standard HDMI sink, in this case a monitor with HDMI input.

7.3.2 Copy the Design Files

After you set up the hardware, you copy the design files.
Copy the hardware demonstration files from one of the following paths to your working directory:

- Arria V
  - 2 symbols per clock (HDMI 1.4b) demonstration: `<IP root directory>/altera_hdmi/hw_demo/av_sk`
  - 4 symbols per clock (HDMI 2.0) demonstration: `<IP root directory>/altera_hdmi/hw_demo/av_sk_hdmi2`
- Stratix V
  - 2 symbols per clock (HDMI 2.0) demonstration: `<IP root directory>/altera_hdmi/hw_demo/sv_hdmi2`

7.3.3 Build and Compile the Design

After you copy the design files, you can build the design.

You can use the provided Tcl script to build and compile the FPGA design.

1. Open a Nios II Command Shell.
2. Change the directory to your working directory.
3. Type the command and enter `source runall.tcl`.
   This script executes the following commands:
   - Generate IP catalog files
   - Generate the Qsys system
   - Create a Quartus Prime project
   - Create a software work space and build the software
   - Compile the Quartus Prime project
   - Run Analysis & Synthesis to generate a post-map netlist for DDR assignments —for VIP passthrough design only
   - Perform a full compilation

   Note: If you are a Linux user, you will get a message `cygpath: command not found`. You can safely ignore this message; the script will proceed to generate the next commands.

7.3.4 View the Results

At the end of the demonstration, you will be able to view the results on the on the standard HDMI sink (monitor).

To view the results of the demonstration, follow these steps:

1. Power up the Intel FPGA board.
2. Type the following command on the Nios II Command Shell to download the Software Object File (`.sof`) to the FPGA.

   `nios2-configure-sof output_files/`<Quartus project name>.sof
3. Power up the standard HDMI source and sink (if you haven't done so).
   The design displays the output of your video source (PC).

Note: If the output does not appear, press `cpu_resetn` to reinitialize the system or perform HPD by unplugging the cable from the standard source and plug it back again.

4. Open the graphic card control utility (if you are using a PC as source). Using the control panel, you can switch between various video resolutions.

   The av_hdmi2 and sv_hdmi2 demonstration designs allow any video resolutions up to 4Kp60. The av_sk design allows *640×480p60*, *720×480p60*, *1280×720p60*, *1920×1080p60*, and *3840×2160p24* when you select the VIP passthrough mode (`user_dipsw[0] = 0`). If you select the VIP bypass mode (`user_dipsw[0] = 1`, the design allows any video resolutions up to 4Kp60.

7.3.4.1 Push Buttons, DIP Switches and LED Functions

Use the push buttons, DIP switches, and LED functions on the board to control your demonstration.

Table 38. Push Buttons, DIP Switches and LEDs Functions

Push Button/ DIP Switch/LED	Pins		Functions
	av_sk/ av_sk_hdmi2	sv_hdmi2	
cpu_resetn	D5	AM34	Press once to perform system reset.
user_pb[0]	A14	A7	Press once to toggle HPD signal to the standard HDMI source.
user_pb[1]	B15	B7	Press and hold to instruct the TX to send DVI encoded signal and release to send HDMI encoded signal.
user_pb[2]	B14	C7	Press and hold to instruct the TX to stop sending InfoFrames and release to resume sending.
user_dipsw[0]	D15	Unused	Only used in av_sk design which demonstrates the VIP passthrough feature. • 0: VIP passthrough • 1: VIP bypass
user_led[0]	F17	J11	RX HDMI PLL lock status. • 0: Unlocked • 1: Locked
user_led[1]	G15	U10	RX transceiver ready status. • 0: Not ready • 1: Ready
user_led[2]	G16	U9	RX HDMI core lock status • 0: At least 1 channel unlocked • 1: All 3 channels locked
user_led[3]	G17	AU24	RX oversampling status. • 0: Non-oversampled (more than 611 Mbps for av_sk and sv_hdmi2, more than 1,000 Mbps for av_sk_hdmi2) • 1: Oversampled (less than 611 Mbps for av_sk and sv_hdmi2, less than 1,000 Mbps for av_sk_hdmi2)

continued...

Push Button/ DIP Switch/LED	Pins		Functions
	av_sk/ av_sk_hdmi2	sv_hdmi2	
user_led[4]	D16	AF28	TX HDMI PLL lock status. • 0: Unlocked • 1: Locked
user_led[5]	C13	AE29	TX transceiver ready status. • 0: Not ready • 1: Ready
user_led[6]	C14	AR7	TX transceiver PLL lock status. • 0: Unlocked • 1: Locked
user_led[7]	C16	AV10	TX oversampling status. • 0: Non-oversampled (more than 611 Mbps for av_sk and sv_hdmi2, more than 1,000 Mbps for av_sk_hdmi2) • 1: Oversampled (less than 611 Mbps for av_sk and sv_hdmi2, less than 1,000 Mbps for av_sk_hdmi2)

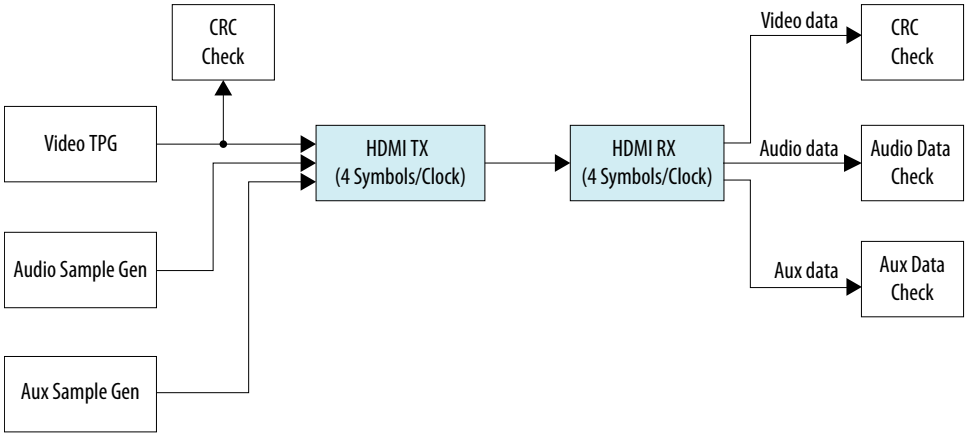
8 HDMI Simulation Example

The HDMI simulation example evaluates the functionality of the HDMI IP core and provides a starting point for you to create your own simulation.

This simulation example targets the ModelSim SE simulator. The simulation covers the following core features:

- IEC-60958 audio format
- Standard H/V/DE/RGB input video format
- Support for 4 symbols per clock
- Support for HDMI 2.0 scrambled operation

Figure 38. HDMI Testbench



The Test Pattern Generator (TPG) provides the video stimulus. The IP core stimulates the HDMI TX core using an audio packet generator and aux packet generator. The output from the HDMI TX core drives the HDMI RX core.

The IP core requires a memory-mapped master stimulus to operate the testbench for HDMI 2.0 scrambling. This stimulus implements the activity normally seen across the I^2C DDC channel. At this point, the IP core asserts the scramble enable bit in the SCDC registers.

The testbench implements CRC checking on the input and output video. The testbench checks the CRC value of the transmitted data against the CRC calculated in the received video data. The testbench performs the checking after detecting 4 stable V-SYNC signals from the receiver.

The aux sample generator generates a fixed data to be transmitted from the transmitter. On the receiver side, the generator compares whether the expected aux data is received and decoded correctly.

The audio sample generator generates an incrementing test data pattern to be transmitted through the audio channel. On the receiver side, the audio data checker checks and compares whether the incrementing test data pattern is received and decoded correctly.

8.1 Simulation Walkthrough

Setting up and running the HDMI simulation example consists of two steps.

1. Copy the simulation files from `<IP root directory>/altera/altera_hdmi/sim_example` to your working directory.
2. Generate the IP simulation files and scripts, compile, and simulate.
   a. Open your command prompt.
   b. Type the command below and enter.

      ```
      sh runall.sh
      ```

      This script executes the following commands:

Command	
Generate the simulation files for the HDMI cores.	• `ip-generate --project-directory=./ --component-file=./hdmi_rx_single.qsys --output-directory=./hdmi_rx_single/sim/ --file-set=SIM_VERILOG --report-file=sopcinfo:./hdmi_rx_single.sopcinfo --report-file=html:./hdmi_rx_single.html --report-file=spd:./hdmi_rx_single/sim/hdmi_rx_single.spd --report-file=qip:./hdmi_rx_single/sim/hdmi_rx_single.qip` • `ip-generate --project-directory=./ --component-file=./hdmi_rx_double.qsys --output-directory=./hdmi_rx_double/sim/ --file-set=SIM_VERILOG --report-file=sopcinfo:./hdmi_rx_double.sopcinfo --report-file=html:./hdmi_rx_double.html --report-file=spd:./hdmi_rx_double/sim/hdmi_rx_double.spd --report-file=qip:./hdmi_rx_double/sim/hdmi_rx_double.qip` • `ip-generate --project-directory=./ --component-file=./hdmi_tx_single.qsys --output-directory=./hdmi_tx_single/sim/ --file-set=SIM_VERILOG --report-file=sopcinfo:./hdmi_tx_single.sopcinfo --report-file=html:./hdmi_tx_single.html --report-file=spd:./hdmi_tx_single/sim/hdmi_tx_single.spd --report-file=qip:./hdmi_tx_single/sim/hdmi_tx_single.qip` • `ip-generate --project-directory=./ --component-file=./hdmi_tx_double.qsys --output-directory=./hdmi_tx_double/sim/ --file-set=SIM_VERILOG --report-file=sopcinfo:./hdmi_tx_double.sopcinfo --report-file=html:./hdmi_tx_double.html --report-file=spd:./hdmi_tx_double/sim/hdmi_tx_double.spd --report-file=qip:./hdmi_tx_double/sim/hdmi_tx_double.qip`
Merge the four resulting `msim_setup.tcl` scripts to create a single `mentor/msim_setup.tcl` script.	`ip-make-simscript --spd=./hdmi_tx_single/sim/hdmi_tx_single.spd --spd=./hdmi_tx_double/sim/hdmi_tx_double.spd --spd=./hdmi_rx_single/sim/hdmi_rx_single.spd --spd=./hdmi_rx_double/sim/hdmi_rx_double.spd`
Compile and simulate the design in the ModelSim software.	`vsim -c -do msim_hdmi.tcl`
Generate the simulation files for the HDMI cores.	
Merge the resulting `msim_setup.tcl` scripts to create a single `mentor/msim_setup.tcl` script.	
Compile and simulate the design in the ModelSim software.	

Example successful result:

```
# SYMBOLS_PER_CLOCK = 4
# VIC = 0
# AUDIO_CLK_DIVIDE = 800
# TEST_HDMI_6G = 1
# Simulation pass
# ** Note: $finish : bitec_hdmi_tb.v (647)
     Time: 15702552 ns Iteration: 3 Instance: /bitec_hdmi_tb
# End time: 14:39:02 on Feb 04,2016, Elapsed time: 0:03:17
# Errors: 0, Warnings: 134
```

A HDMI IP Core User Guide Archives

If an IP core version is not listed, the user guide for the previous IP core version applies.

IP Core Version	User Guide
16.1	HDMI IP Core User Guide
16.0	HDMI IP Core User Guide
15.1	HDMI IP Core User Guide
15.0	HDMI IP Core User Guide
14.1	HDMI IP Core User Guide

B Document Revision History for HDMI User Guide

Date	Version	Changes
May 2017	2017.05.08	• Rebranded as Intel. • Added recommended speed grades for Arria 10 devices.
December 2016	2016.12.20	• Updated the HDMI IP core resource utilization table with 16.1 information. • Added a note for YCbCr 4:2:2 video format that 8 and 10 bits per color use the same pixel encoding as 12 bits per color, but the valid bits are left-justified with zeroes padding the bits below the least significant bit. • Added information for the new Design Example parameters. • Removed all Arria 10 design example related information. For more information about Arria 10 design examples, refer to the *HDMI IP Core Design Example User Guide*. • Edited the typos in the HDMI Audio Format topic. • Added information that the HDMI IP core does not support 8-channel audio. • Added a new output port `version[31:0]` for HDMI source and sink.
May 2016	2016.05.02	• Updated the HDMI IP core resource utilization table with 16.0 information. • Added information about Audio Metadata Packet for *HDMI Specification Version 2.0*. • Added information about new HDMI source ports: — `audio_metadata[164:0]` — `audio_format[4:0]` • Added information about new HDMI sink ports: — `audio_metadata[164:0]` — `audio_format[4:0]` — `vid_lock` — `aux_error` • Provided detailed information about the HDMI source and sink `audio_de[7:0]` port. • Updated the testbench diagram and description to include audio data and auxiliary data information. • Added a note for Altera PLL to place the PLL in the transmit path (`pll_hdmi_tx`) in the physical location next to the transceiver PLL. • Updated the HDMI sideband signals (HDMI AVI and VSI bit-fields) with default values. • Added links to archived versions of the *HDMI IP Core User Guide*.
November 2015	2015.11.02	• Updated the HDMI IP core resource utilization table with 15.1 information. • Changed instances of *Quartus II* to *Quartus Prime*. • Added full support for Arria 10 devices. • Added support for new features: — Deep color — 8-channel audio • Added the following parameters for HDMI source: — **Support for 8-channel audio** — **Support for deep color**

continued...

Date	Version	Changes
		• Added the following parameters for HDMI sink: — **Support for 8-channel audio** — **Support for deep color** — **Manufacturer OUI** — **Device ID String** — **Hardware Revision** • Updated the following interface ports for HDMI source: — Added `ctrl` port — Removed `gcp_Set_AVMute` and `gcp_Clear_AVMute` ports • Updated the following interface ports for HDMI sink: — Added `ctrl` , `mode`, `in_5v_power`, and `in_hpd` ports — Removed `gcp_Set_AVMute` and `gcp_Clear_AVMute` ports • Updated the HDMI sink and source block diagrams to reflect the new features. • Provided block diagrams for deep color mapping. • Generalized the HDMI hardware demonstration design for all supported device families (Arria V, Stratix V, and Arria 10) with detailed description.
May 2015	2015.05.04	• Updated the HDMI IP core resource utilization table with 15.0 information. • Added information about 4 symbols per clock mode. • Added information about Status and Control Data Channel (SCDC) for *HDMI specification version 2.0*. • Added the following interface ports for HDMI source: — `TMDS_Bit_clock_Ratio` — `Scrambler_Enable` • Added the `TMDS_Bit_clock_Ratio` interface port for HDMI sink. • Updated the HDMI hardware demonstration design with HDMI 2.0 information. • Added software process flow for the HDMI hardware demonstration.
December 2014	2014.12.15	Initial release.