HDMI 1.4/2.0 Receiver Subsystem v2.0

Product Guide

Vivado Design Suite

PG236 April 5, 2017
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Introduction

The HDMI 1.4/2.0 Receiver Subsystem is a hierarchical IP that bundles a collection of HDMI® RX IP sub-cores and outputs them as a single IP. It is an out-of-the-box ready-to-use HDMI 1.4/2.0 Receiver Subsystem and avoids the need to manually assemble sub-cores to create a working HDMI RX system.

Features

- HDMI 2.0 and 1.4b compatible
- 2 or 4 symbol/pixel per clock input
- Supports resolutions up to 4,096 x 2,160 @ 60 fps
- 8, 10, 12, and 16-bit Deep-color support
- Support color space for RGB, YUV 4:4:4, YUV 4:2:2, YUV 4:2:0
- Support AXI4-Stream Video output stream and Native Video output stream
- Audio support for up to 8 channels
- Info frames
- Data Display Channel (DDC)
- Hot-Plug Detection
- 3D video support
- Optional High Bandwidth Digital Copy Protection (HDCP) 1.4 support
- Optional HDCP 2.2 support
- Optional Video over AXIS compliant NTSC/PAL Support
- Optional Video over AXIS compliant YUV420 Support
- Optional HPD Active polarity
- Optional Cable Detect Active polarity

LogiCORE™ IP Facts Table

<table>
<thead>
<tr>
<th>Subsystem Specifics</th>
<th>Supported Device Family(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UltraScale+™ Families (GTHE4)</td>
</tr>
<tr>
<td></td>
<td>UltraScale™ Architecture (GTHE3)</td>
</tr>
<tr>
<td></td>
<td>Zynq®-7000 All Programmable SoC</td>
</tr>
<tr>
<td></td>
<td>7 Series (GTXE2, GTHE2)</td>
</tr>
<tr>
<td></td>
<td>Artix®-7 (GTPE2)</td>
</tr>
</tbody>
</table>

| Supported User Interfaces | AXI4-Lite, AXI4-Stream |

| Resources | Performance and Resource Utilization web page |

Provided with Subsystem

| Design Files | RTL |
| Test Bench | Not Provided |
| Constraints File | XDC |
| Simulation Model | Not Provided |
| Supported S/W Driver(2) | Standalone |

Tested Design Flows(3)

| Design Entry | Vivado® Design Suite |
| Simulation | For supported simulators, see the Xilinx Design Tools: Release Notes Guide. |
| Synthesis | Vivado Synthesis |

Notes:
1. For a complete list of supported devices, see the Vivado IP catalog.
2. Standalone driver details can be found in the SDK directory (<install_directory>/doc/usenglish/xilinx_drivers.htm). Linux OS and driver support information is available from the Xilinx Wiki page.
3. For the supported versions of the tools, see the Xilinx Design Tools: Release Notes Guide.
Overview

The HDMI 1.4/2.0 Receiver Subsystem is a feature-rich soft IP incorporating all the necessary logic to properly interface with PHY layers and provide HDMI decoding functionality. The subsystem is a hierarchical IP that bundles a collection of HDMI RX-related IP sub-cores and outputs them as a single IP. The subsystem receives the captured TMDS data from the video PHY layer. It then extracts the video and audio streams from the HDMI stream and converts it to video and audio streams.

The subsystem can be configured at design time through a single interface in the Vivado® Integrated Design Environment (IDE) for performance and quality.

Applications

High-Definition Multimedia Interface (HDMI) is a common interface used to transport video and audio and is seen in almost all consumer video equipment such as DVD and media players, digital televisions, camcorders, mobile tablets and phones. The omnipresence of the interface has also spread to most professional equipment such as professional cameras, video switchers, converters, monitors and large displays used in video walls and public display signs.

For tested video resolutions for the subsystem see Appendix A, Verification, Compliance, and Interoperability.

Unsupported Features

The following features are not supported in this subsystem:

- Lip sync
- CEC
- HEAC
- HDMI 2.0 dual view
- HDMI 2.0 multi stream audio
Licensing and Ordering Information

License Checkers

If the IP requires a license key, the key must be verified. The Vivado® design tools have several license checkpoints for gating licensed IP through the flow. If the license check succeeds, the IP can continue generation. Otherwise, generation halts with error. License checkpoints are enforced by the following tools:

- Vivado synthesis
- Vivado implementation
- write_bitstream (Tcl command)

**IMPORTANT:** IP license level is ignored at checkpoints. The test confirms a valid license exists. It does not check IP license level.

If a Hardware Evaluation License is being used, the core stops transmitting HDMI Stream after timeout. This timeout is based on system CPU clock. For example, if system is running at 100 Mhz, the IP times out after approximately 4 hours of normal operation when Hardware Evaluation License is being used.

License Type

This Xilinx® LogiCORE™ IP module is provided under the terms of the Xilinx Core License Agreement. The module is shipped as part of the Vivado® Design Suite. For full access to all subsystem functionalities in simulation and in hardware, you must purchase a license for the subsystem. Contact your local Xilinx sales representative for information about pricing and availability.

For more information, visit the Xilinx HDMI web page.

Information about other Xilinx LogiCORE IP modules is available at the Xilinx Intellectual Property page. For information on pricing and availability of other Xilinx LogiCORE IP modules and tools, contact your local Xilinx sales representative.
Chapter 2

Product Specification

This chapter includes a description of the subsystem and details about the performance and resource utilization.

A high-level block diagram of the HDMI 1.4/2.0 Receiver Subsystem is shown in Figure 2-1.

![Figure 2-1: Subsystem Block Diagram](image)

The HDMI RX Subsystem is constructed on top of an HDMI RX core. Various supporting modules are added around the HDMI RX core with respect to your configuration. The HDMI RX core is designed to support native video interface, however many of the existing video processing IP cores are AXI4-Stream based. It is a natural choice to add a converter module (Video In to AXI4-Stream) to enable the HDMI RX Subsystem to output AXI4-Stream based video. By performing this, HDMI RX Subsystem is able to work seamlessly with other Xilinx video processing IP cores. The HDMI RX Subsystem has a built-in capability to optionally support both HDCP 1.4 and HDCP 2.2 decryption.

Figure 2-2 shows the internal structure of the HDMI RX Subsystem when **AXI4-Stream Video Interface** is selected as video interface. In this illustration, both HDCP 1.4 and HDCP 2.2 are selected and both Video over AXIS compliant NTSC/PAL Support and Video over AXIS compliant YUV420 Support are selected.

The HDMI 1.4/2.0 Receiver Subsystem supports two types of video interface:
The HDMI RX Subsystem also provides an option to support a native video interface by constructing the HDMI RX Subsystem without the Video In to AXI4-Stream Bridging module. Therefore, the HDMI RX Subsystem is allowed to output native video to its own video devices. In native video mode, the HDMI RX Subsystem still has a built-in capability to optionally support both HDCP 1.4 and HDCP 2.2 decryption.

Figure 2-3 shows the internal structure of the HDMI RX Subsystem when **Native Video Interface** is selected as video interface. In this illustration, both HDCP 1.4 and HDCP 2.2 are selected.

The data width of the video interface is configured in the Vivado IDE by setting the **Number of Pixels Per Clock on Video Interface** and the **Max Bits Per Component** parameters.

The audio interface is a 32-bit AXI4-Stream master bus. The subsystem converts the captured audio to a multiple channel AXI audio stream and outputs the audio data on this interface.
The CPU interface is an AXI4-Lite bus interface, which is connected to a MicroBlaze™ or Zynq®-7000 SoC processor. Multiple submodules are used to construct the HDMI RX Subsystem and all the submodules which require software access are connected through an AXI crossbar. Therefore, the MicroBlaze or Zynq-7000 SoC processor is able to access and control each individual submodules inside the HDMI RX Subsystem.

**IMPORTANT:** The direct register level access to any of the submodules is not supported.

The HDMI RX Subsystem device driver has an abstract layer of API to allow you to implement certain functions. This AXI4-Lite slave interface supports single beat read and write data transfers (no burst transfers).

The HDMI RX subsystem is connected to a Xilinx Video PHY Controller, which takes electronic signals from a HDMI cable and translates it into HDMI stream. Then, the HDMI RX subsystem converts the HDMI stream into native video stream and audio stream. Based on the configuration selected, the HDMI RX Subsystem sends the video stream in either Native Video format or AXI4-Stream format together with the AXI4-Stream Audio to other processing modules.

The subsystem also supports the features described in the following sections.

### Audio Clock Regeneration Signals

The subsystem can output Audio Clock Regeneration (ACR) signals that allow receiver audio peripherals to regenerate the audio clock.

The audio clock regeneration architecture is not part of the HDMI RX subsystem. You must provide an audio clock to the application. This can be achieved by using an internal PLL or external clock source, depending on the audio clock requirements, audio sample frequency and jitter. When HDMI TX subsystem is used in DVI mode, the ACR inputs are ignored. You can decide to leave them open or connect them to some fix values (for example, connecting acr_cts, acr_n, and acr_valid to 0). When HDMI RX subsystem is used in DVI mode, the ACR outputs can be left unconnected. See Chapter 5, Example Design for an example ACR module that is part of the audio pattern generation system.

### Display Data Channel (DDC)

The subsystem allows the end-user to build an HDMI sink device, which negotiates with the targeted HDMI source device for supported features and capabilities. The communication between the source device(s) and the sink device is implemented through the DDC lines, which is an I2C bus included on the HDMI cable.

### Hot Plug Detect

The subsystem supports the Hot Plug Detect (HPD) feature, which is a communication mechanism between HDMI source and HDMI sink devices. For example, when an HDMI
cable is inserted between the HDMI source and HDMI sink devices, the cable-detect signal is asserted. The subsystem then outputs a hpd signal, which triggers the start of a communication between the source device and sink device.

**InfoFrames**

There are two basic InfoFrames expected in any HDMI system, which are Auxiliary Video Information (AVI) Infoframe and Audio Infoframe. An InfoFrame is structured with a 4-byte header and 32-byte data (payload). All InfoFrames types are described in detail in CEA-861-F.

In the HDMI RX Subsystem driver, there is a generic API function for you to retrieve the InfoFrame. This is an example of a function call:

```c
u8 AuxBuffer[36];
memcpy(AuxBuffer, XV_HdmiRxSs_GetAuxiliary(&HdmiRxSsPtr), sizeof(AuxBuffer));
```

HdmiRxSsPtr is a pointer to the HDMI RX Subsystem, and AuxBuffer is a local buffer allocated to store the AUX InfoFrame header and payload data.

**Figure 2-4** a graphically represents an HDMI Infoframe structure, which is one type of HDMI data island packet. For HDMI, all data island packets consist of a 4-byte packet header and a 32 bytes of packet contents. The packet header contains 24 data bits (3 bytes) and 8 bits (1 byte) of BCH ECC parity.

<table>
<thead>
<tr>
<th>Byte\Bit</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
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<td>H80</td>
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<td></td>
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<td>Packet Type</td>
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<td>H81</td>
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<td>packet-specific data</td>
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<td></td>
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<tr>
<td>H82</td>
<td></td>
<td>packet-specific data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2-4:** Packet Header

The packet body, graphically represented in **Figure 2-5**, is made from four subpackets; each subpacket includes 56 bits (7 bytes) of data and 8 bits (1 byte) of BCH ECC parity.
### Notes:

1. ECC is calculated in HDMI 1.4/2.0 Receiver Subsystem core. Therefore, must construct HB0…HB2, and PB0, PB1…PB26, PB27 according to HDMI specs in the software.
2. When calculating the checksum value (PB0), the ECC values are ignored.

Refer to section 5.2.3.4 and 5.2.3.5 of the HDMI 1.4 Specification [Ref 10] for more information on the InfoFrame structure.

### HDCP

As part of the HDMI RX Subsystem, the Xilinx® LogiCORE™ IP High-bandwidth Digital Content Protection (HDCP™) receivers are designed for receiving of audiovisual content securely between two devices that are HDCP capable. In this HDMI RX Subsystem, both HDCP 1.4 and HDCP 2.2 Receiver IP cores are included. However because HDCP 2.2 supersedes the HDCP 1.4 protocol and does not provide backwards compatibility, you need to decide and choose targeted content protection schemes from the Vivado IDE. Four different options are available to choose from:

- No HDCP
- HDCP 1.4 only
- HDCP 2.2 only
- HDCP 1.4 and HDCP 2.2

<table>
<thead>
<tr>
<th>Subpacket #</th>
<th>Byte/Bit #</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subpacket 0 (Checksum + 6 data bytes + ECC)</td>
<td>PB0</td>
<td>Checksum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PB1</td>
<td>Data Byte 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PB2…PB5</td>
<td>Data Byte 2 - Data Byte 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>PB6</td>
<td>Data Byte 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECC1</td>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subpacket 1 (7 Data Bytes + ECC)</td>
<td>PB7</td>
<td>Data Byte 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PB8…PB12</td>
<td>Data Byte 8 - Data Byte 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PB13</td>
<td>Data Byte 13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECC2</td>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Subpacket 2 (7 Data Bytes + ECC)</td>
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<td>Data Byte 14</td>
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<tr>
<td></td>
<td>PB15…PB19</td>
<td>Data Byte 15 - Data Byte 19</td>
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<td></td>
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<td></td>
<td>PB20</td>
<td>Data Byte 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECC3</td>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subpacket 3 (7 Data Bytes + ECC)</td>
<td>PB21</td>
<td>Data Byte 21</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>PB22…PB26</td>
<td>Data Byte 22 - Data Byte 26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PB27</td>
<td>Data Byte 27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECC3</td>
<td>ECC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2-5: Packet Body*
As a guideline, HDCP 2.2 is used to decrypt content at Ultra-High Definition (UHD) while HDCP 1.4 is the legacy content protection scheme used at lower resolutions.

**Figure 2-6** shows a configuration of the HDMI receiver where both HDCP 1.4 and 2.2 are enabled. With both HDCP protocols enabled, the HDMI Subsystem configures itself in the cascade topology where the HDCP 1.4 and HDCP 2.2 are connected back-to-back. The HDCP Egress interface of the HDMI receiver sends encrypted audiovisual data, which is decrypted by the active HDCP block and sent back into the HDMI receiver over the HDCP Ingress interface to send to other video processing modules in the system through AXI4-Stream Video interface or Native Video interface. The HDMI receiver subsystem ensures that only one of the HDCP protocols are active at any given time and the other is passive by calling the relevant HDMI RX Subsystem API functions.

---

**Standards**

The HDMI 1.4/2.0 Receiver Subsystem is compliant with the AXI4-Stream Video Protocol and AXI4-Lite interconnect standards. See the *Vivado AXI Reference Guide* (UG1037) [Ref 1] for additional information. Also, see HDMI specifications [Ref 10].

The HDMI RX Subsystem is compliant with the HDMI 1.4b and HDMI 2.0 specification [Ref 10].

The Xilinx HDCP 1.4 is designed to be compatible with High-bandwidth Digital Content Protection system Revision 1.4 [Ref 11].

The Xilinx HDCP 2.2 is compliant with the HDCP 2.2 specification entitled High-bandwidth Digital Content Protection, Mapping HDCP to HDMI, Revision 2.2, issued by Digital Content Protection (DCP) LLC [Ref 11].
Performance

For full details about performance and resource utilization, visit the Performance and Resource Utilization web page.

Maximum Frequencies

Refer to the following documents for information on DC and AC switching characteristics. The frequency ranges specified in these documents must be adhered to for proper transceiver and core operation.

- **Kintex UltraScale FPGAs Data Sheet: DC and AC Switching Characteristics** (DS892) [Ref 2]
- **Virtex UltraScale FPGAs Data Sheet: DC and AC Switching Characteristics** (DS893) [Ref 3]
- **Kintex-7 FPGAs Data Sheet: DC and AC Switching Characteristics** (DS182) [Ref 4]
- **Virtex-7 FPGAs Data Sheet: DC and AC Switching Characteristics** (DS183) [Ref 5]
- **Artix-7 FPGAs Data Sheet: DC and AC Switching Characteristics** (DS181) [Ref 6]
- **Kintex UltraScale+ FPGAs Data Sheet: DC and AC Switching Characteristics** (DS922) [Ref 7]
- **Virtex UltraScale+ FPGAs Data Sheet: DC and AC Switching Characteristics** (DS923) [Ref 8]
- **Zynq UltraScale+ MPSoC Data Sheet: DC and AC Switching Characteristics** (DS925) [Ref 9]

Resource Utilization

For full details about performance and resource utilization, visit the Performance and Resource Utilization web page.

Port Descriptions

*Figure 2-7 to Figure 2-10* show the HDMI 1.4/2.0 Receiver Subsystem ports when AXI4-Stream is selected as video interface. The VIDEO_OUT port is expanded in the figure to show the detail AXI4-Stream Video bus signals.

The following subsystem has three default interfaces:
- AXI4-Lite control interface (S_AXI_CPU_IN)
- Video Interface (VIDEO_IN)
- Audio Interface (AUDIO_IN)

**Figure 2-7:** HDMI RX Subsystem Pinout – AXI4-Stream Video Interface (No HDCP)
Figure 2-8: HDMI RX Subsystem Pinout – AXI4-Stream Video Interface (HDCP 1.4 Only)
Figure 2-9: HDMI RX Subsystem Pinout – AXI4-Stream Video Interface (HDCP 2.2 Only)
Chapter 2: Product Specification

Figure 2-10: HDMI RX Subsystem Pinout – AXI4-Stream Video Interface
(HDCP 1.4 and HDCP 2.2)

Figure 2-11 to Figure 2-14 show the HDMI 1.4/2.0 Receiver Subsystem ports when Native Video is selected as video interface. The VIDEO_OUT port is expanded in the figure to show the detail Native Video bus signals.
Figure 2-11: HDMI RX Subsystem Pinout – Native Video Interface (No HDCP)
Figure 2-12: HDMI RX Subsystem Pinout – Native Video Interface (HDCP 1.4 Only)
Figure 2-13: HDMI RX Subsystem Pinout – Native Video Interface (HDCP 2.2 Only)
**Figure 2-14:** HDMI RX Subsystem Pinout – Native Video Interface (HDCP 1.4 and HDCP 2.2)
CPU Interface

Table 2-1 shows the AXI4-Lite control interface signals. This interface is an AXI4-Lite interface and runs at the `s_axi_cpu_aclk` clock rate. Control of the subsystem is only supported through the subsystem driver.

IMPORTANT: The direct register level access to any of the submodules is not supported. Instead, all the accesses are done through driver APIs.

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>s_axi_cpu_arstn</td>
<td>Input</td>
<td>1</td>
<td>Reset (Active-Low)</td>
</tr>
<tr>
<td>s_axi_cpu_aclk</td>
<td>Input</td>
<td>1</td>
<td>Clock for AXI4-Lite control interface</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_awaddr</td>
<td>Input</td>
<td>18</td>
<td>Write address</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_awprot</td>
<td>Input</td>
<td>3</td>
<td>Write address protection</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_awvalid</td>
<td>Input</td>
<td>1</td>
<td>Write address valid</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_awready</td>
<td>Output</td>
<td>1</td>
<td>Write address ready</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_wdata</td>
<td>Input</td>
<td>32</td>
<td>Write data</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_wstrb</td>
<td>Input</td>
<td>4</td>
<td>Write data strobe</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_wvalid</td>
<td>Input</td>
<td>1</td>
<td>Write data valid</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_wready</td>
<td>Output</td>
<td>1</td>
<td>Write data ready</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_bresp</td>
<td>Output</td>
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<td>S_AXI_CPU_IN_bvalid</td>
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<td>Write response valid</td>
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<td>S_AXI_CPU_IN_bready</td>
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<td>Write response ready</td>
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<td>Read address</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_arprot</td>
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<td>3</td>
<td>Read address protection</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_arvalid</td>
<td>Input</td>
<td>1</td>
<td>Read address valid</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_aready</td>
<td>Output</td>
<td>1</td>
<td>Read address ready</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_rdata</td>
<td>Output</td>
<td>32</td>
<td>Read data</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_rresp</td>
<td>Output</td>
<td>2</td>
<td>Read data response</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_rvalid</td>
<td>Output</td>
<td>1</td>
<td>Read data valid</td>
</tr>
<tr>
<td>S_AXI_CPU_IN_rready</td>
<td>Input</td>
<td>1</td>
<td>Read data ready</td>
</tr>
</tbody>
</table>
Video Output Stream Interface

This HDMI 1.4/2.0 Receiver Subsystem is supporting two types of video output stream interfaces, which eventually is mapped to HDMI 1.4/2.0 Receiver Subsystem VIDEO_OUT interface.

- AXI4-Stream Video interface
- Native Video Interface

Table 2-2 shows the signals for AXI4-Stream video output streaming interface. This interface is an AXI4-Stream master interface and runs at the $s_{\text{axis}_\text{video}_\text{aclk}}$ clock rate. The data width is user-configurable in the Vivado IDE by setting Max Bits Per Component (BPC) and Number of Pixels Per Clock on Video Interface (PPC).

Table 2-2: Video Output Stream Interface

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_{\text{axis}<em>\text{video}</em>\text{aclk}}$</td>
<td>Input</td>
<td>1</td>
<td>AXI4-Stream clock</td>
</tr>
<tr>
<td>$s_{\text{axis}<em>\text{video}</em>\text{aresetn}}$</td>
<td>Input</td>
<td>1</td>
<td>Reset (Active-Low)</td>
</tr>
<tr>
<td>VIDEO_OUT_tdata</td>
<td>Output</td>
<td>3<em>BPC</em>PPC</td>
<td>Data</td>
</tr>
<tr>
<td>VIDEO_OUT_tlast</td>
<td>Output</td>
<td>1</td>
<td>End of line</td>
</tr>
<tr>
<td>VIDEO_OUT_tready</td>
<td>Input</td>
<td>1</td>
<td>Ready</td>
</tr>
<tr>
<td>VIDEO_OUT_tuser</td>
<td>Output</td>
<td>1</td>
<td>Start of frame</td>
</tr>
<tr>
<td>VIDEO_OUT_tvalid</td>
<td>Output</td>
<td>1</td>
<td>Valid</td>
</tr>
</tbody>
</table>

Native Video Output Interface

Table 2-3 shows the signals for Native video output interface. This interface is a standard video interface and runs at video_clk clock rate. The data width is user-configurable in the Vivado IDE by setting Max Bits Per Component (BPC) and Number of Pixels Per Clock on Video Interface (PPC).

Table 2-3: Native Video Output Interface

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>video_clk</td>
<td>Input</td>
<td>1</td>
<td>Video clock</td>
</tr>
<tr>
<td>VIDEO_OUT_field</td>
<td>Output</td>
<td>1</td>
<td>Field ID (only for interlaced video)</td>
</tr>
<tr>
<td>VIDEO_OUT_active_video</td>
<td>Output</td>
<td>1</td>
<td>Active video</td>
</tr>
<tr>
<td>VIDEO_OUT_data</td>
<td>Output</td>
<td>3<em>BPC</em>PPC</td>
<td>Data</td>
</tr>
<tr>
<td>VIDEO_OUT_hsync</td>
<td>Output</td>
<td>1</td>
<td>Horizontal sync</td>
</tr>
</tbody>
</table>
Audio Output Stream Interface

Table 2-4 shows the signals for AXI4-Stream audio output streaming interfaces. The audio interface transports 24-bits audio samples in the IEC 60958 format. A maximum of eight channels are supported. The audio interface is a 32-bit AXI4-Stream master interface and runs at the s_axis_audio_aclk clock rate.

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>s_axis_audio_aclk</td>
<td>Input</td>
<td>1</td>
<td>Clock (The audio streaming clock must be greater than or equal to 128 times</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the audio sample frequency)</td>
</tr>
<tr>
<td>s_axis_audio_aresetn</td>
<td>Input</td>
<td>1</td>
<td>Reset (Active-Low)</td>
</tr>
<tr>
<td>AUDIO_OUT_tdata</td>
<td>Output</td>
<td>32</td>
<td>Data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[31] P (Parity)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[30] C (Channel status)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[29] U (User bit)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[28] V (Validity bit)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[27:4] Audio sample word</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[3:0] Preamble code</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4'b0001 Subframe 1/start of audio block</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4'b0010 Subframe 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4'b0011 Subframe 2</td>
</tr>
<tr>
<td>AUDIO_OUT_tid</td>
<td>Output</td>
<td>3</td>
<td>Channel ID</td>
</tr>
<tr>
<td>AUDIO_OUT_tready</td>
<td>Input</td>
<td>1</td>
<td>Ready</td>
</tr>
<tr>
<td>AUDIO_OUT_tvalid</td>
<td>Output</td>
<td>1</td>
<td>Valid</td>
</tr>
</tbody>
</table>

Audio Clock Regeneration Interface

The audio clock regeneration (ACR) interface has a Cycle Time Stamp (CTS) parameter vector and an Audio Clock Regeneration Value (N) parameter vector. Both vectors are 20 bits wide. The valid signal is driven High when the CTS and N parameters are stable. For more information, see Chapter 7 of the HDMI 1.4 specification [Ref 10].
The subsystem should set up the CTS and N parameters before asserting the valid signal.

**Table 2-5** shows the Audio Clock Regeneration (ACR) interface signals. This interface runs at the `s_axis_audio_aclk` clock rate.

**Table 2-5: Audio Clock Regeneration (ACR) Interface**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>acr_cts</td>
<td>Output</td>
<td>20</td>
<td>CTS</td>
</tr>
<tr>
<td>acr_n</td>
<td>Output</td>
<td>20</td>
<td>N</td>
</tr>
<tr>
<td>acr_valid</td>
<td>Output</td>
<td>1</td>
<td>Valid</td>
</tr>
</tbody>
</table>

**HDMI Link Input Interface**

**Table 2-6** shows the HDMI Link Input interface signals. This interface runs at the `link_clk` clock rate.

**Table 2-6: HDMI Link Input Interface**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>link_clk</td>
<td>Input</td>
<td>1</td>
<td>Link clock</td>
</tr>
<tr>
<td>LINK_DATA0_IN_tdata</td>
<td>Input</td>
<td>40</td>
<td>Link data 0</td>
</tr>
<tr>
<td>LINK_DATA0_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Link Data 0 Valid</td>
</tr>
<tr>
<td>LINK_DATA1_IN_tdata</td>
<td>Input</td>
<td>40</td>
<td>Link data 1</td>
</tr>
<tr>
<td>LINK_DATA1_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Link Data 1 Valid</td>
</tr>
<tr>
<td>LINK_DATA2_IN_tdata</td>
<td>Input</td>
<td>40</td>
<td>Link data 2</td>
</tr>
<tr>
<td>LINK_DATA2_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Link Data 2 Valid</td>
</tr>
</tbody>
</table>

**Data Display Channel Interface**

**Table 2-7** shows the Data Display Channel interface signals.

**Table 2-7: Data Display Channel (DDC) Interface**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ddc_scl_i</td>
<td>Input</td>
<td>1</td>
<td>DDC serial clock in</td>
</tr>
<tr>
<td>ddc_scl_o</td>
<td>Output</td>
<td>1</td>
<td>DDC serial clock out</td>
</tr>
<tr>
<td>ddc_scl_t</td>
<td>Output</td>
<td>1</td>
<td>DDC serial clock tri-state</td>
</tr>
<tr>
<td>ddc_sda_i</td>
<td>Input</td>
<td>1</td>
<td>DDC serial data in</td>
</tr>
<tr>
<td>ddc_sda_o</td>
<td>Output</td>
<td>1</td>
<td>DDC serial data out</td>
</tr>
<tr>
<td>ddc_sda_t</td>
<td>Output</td>
<td>1</td>
<td>DDC serial data tri-state</td>
</tr>
</tbody>
</table>
HDCP 1.4 Key Input Interface (AXI4-Stream Slave Interface)

Table 2-8 shows the signals for HDCP 1.4 key interface. This interface runs at the hdcp14_key_aclk.

**Table 2-8:**  HDCP 1.4 Key Input Interface

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDCP_KEY_IN_tdata</td>
<td>Input</td>
<td>64</td>
<td>HDCP 1.4 key data</td>
</tr>
<tr>
<td>HDCP_KEY_IN_tlast</td>
<td>Input</td>
<td>1</td>
<td>End of key data</td>
</tr>
<tr>
<td>HDCP_KEY_IN_tready</td>
<td>Output</td>
<td>1</td>
<td>Ready</td>
</tr>
<tr>
<td>HDCP_KEY_IN_tuser</td>
<td>Input</td>
<td>8</td>
<td>Start of key data</td>
</tr>
<tr>
<td>HDCP_KEY_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Valid</td>
</tr>
<tr>
<td>hdcp14_key_aclk</td>
<td>Output</td>
<td>1</td>
<td>AXI4-Stream clock</td>
</tr>
<tr>
<td>hdcp14_key_aresetn</td>
<td>Output</td>
<td>1</td>
<td>Reset (Active-Low)</td>
</tr>
<tr>
<td>hdcp14_start_key_transmit</td>
<td>Output</td>
<td>1</td>
<td>Start key transmit</td>
</tr>
<tr>
<td>hdcp14_reg_key_sel</td>
<td>Output</td>
<td>3</td>
<td>Key select</td>
</tr>
<tr>
<td>hdcp14_irq</td>
<td>Output</td>
<td>1</td>
<td>HDCP 1.4 interrupt</td>
</tr>
<tr>
<td>hdcp14_timer_irq</td>
<td>Output</td>
<td>1</td>
<td>HDCP 1.4 timer interrupt</td>
</tr>
</tbody>
</table>

For the HDCP 1.4 receiver, an HDCP Key Management module is needed, which is able to send keys over the AXI4-Stream interface to the HDCP 1.4 controller. **Figure 2-15** shows an example of how the HDMI RX Subsystem is connected to the HDCP Key Management module through a Key Management Bus (AXI4-Stream). The HDCP Key Management module is not part of the HDMI RX Subsystem. For HDCP 1.4 design details, see the *HDCP v1.4 Product Guide* (PG224) [Ref 24].

![Figure 2-15: HDCP 1.4 Key Management Bus (AXI4-Stream)](image)

However, the HDCP 2.2 key is handled slightly differently as it is solely controlled by the software application. The user application is responsible for providing the infrastructure to securely store and retrieve the keys to be loaded into the HDCP 2.2 drivers. For the detailed list of keys that are required to be loaded by the user application, see the *HDCP v2.2 Product Guide* (PG249) [Ref 23].
**Chapter 2: Product Specification**

**HDCP 2.2 Interrupt Outputs**

Table 2-9 shows the signals for HDCP 2.2 interrupt output ports.

**Table 2-9: HDCP 2.2 Interrupt Output Interface**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hdcp22_irq</td>
<td>Output</td>
<td>1</td>
<td>HDCP 2.2 interrupt</td>
</tr>
<tr>
<td>hdcp22_timer_irq</td>
<td>Output</td>
<td>1</td>
<td>HDCP 2.2 timer interrupt</td>
</tr>
</tbody>
</table>

**Miscellaneous Signals with AXI4-Stream Video Interface**

Table 2-10 shows the miscellaneous signals with AXI4-Stream video interface selected.

**Table 2-10: Miscellaneous Signals with AXI4-Stream Video Interface**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hpd</td>
<td>Output</td>
<td>1</td>
<td>If XGUI option: Hot Plug Detect Active High (Default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Hot Plug Detect is released</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Hot Plug Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If XGUI option: Hot Plug Detect Active Low (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Hot Plug Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Hot Plug Detect is released</td>
</tr>
<tr>
<td>cable_detect</td>
<td>Input</td>
<td>1</td>
<td>If XGUI option: Cable Detect Active High (Default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Cable Detect is released</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Cable Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If XGUI option: Cable Detect Active Low (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Cable Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Cable Detect is released</td>
</tr>
<tr>
<td>irq</td>
<td>Output</td>
<td>1</td>
<td>Interrupt request for CPU. Active-High.</td>
</tr>
<tr>
<td>video_clk</td>
<td>Input</td>
<td>1</td>
<td>Reference Native Video Clock</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>When AXI4-Stream is selected as Video Interface, a Video In to AXI4-Stream</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bridge module is added to the HDMI RX Subsystem to convert Native Video into</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AXI4-Stream Video. HDMI RX core uses this video_clk to clock out the Video</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data.</td>
</tr>
<tr>
<td>SB_STATUS_IN_tdata</td>
<td>Input</td>
<td>2</td>
<td>Side Band Status input signals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 0: link_rdy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 1: video_rdy</td>
</tr>
<tr>
<td>SB_STATUS_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Side Band Status input valid</td>
</tr>
<tr>
<td>fid</td>
<td>Output</td>
<td>1</td>
<td>Field ID for AXI4-Stream bus. Used only for interlaced video.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - even field</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - odd field</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For progress video the output is always Low.</td>
</tr>
</tbody>
</table>
1. The Hot Plug Detect (HPD) signal is driven by an HDMI sink and asserted when the HDMI cable is connected to notify the HDMI source of the presence of an HDMI sink. When designing a HDMI sink system using HDMI Receiver Subsystem, in the PCB, if you choose to use a voltage level shifter, the HPD polarity remains as Active High. However, if you choose to add an inverter to the HPD signal, then the HPD polarity must be set to Active Low in HDMI Receiver Subsystem GUI. There are two common ways of using HPD: Toggle HPD to trigger HDCP authentication process (usually 100 ~ 500ms). Or a longer HPD toggle (>1s), the HDMI sink is notifying the source its present without cable unplug and plug. The software API used to assert and release HPD is XV_HdmiRxSs_SetHpd.

2. The Cable Detect signal is connected to a 5V power signal from the HDMI cable connector via some level shifter to notify the HDMI RX Subsystem that a HDMI source is connected.

**Miscellaneous Signals with Native Video Interface**

Table 2-11 shows the miscellaneous signals with native video interface selected.

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hpd</td>
<td>Input</td>
<td>1</td>
<td>If XGUI option: Hot Plug Detect Active High (Default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Hot Plug Detect is released</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Hot Plug Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If XGUI option: Hot Plug Detect Active Low (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Hot Plug Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Hot Plug Detect is released</td>
</tr>
<tr>
<td>cable_detect</td>
<td>Input</td>
<td>1</td>
<td>If XGUI option: Cable Detect Active High (Default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Cable Detect is released</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Cable Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If XGUI option: Cable Detect Active Low (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Cable Detect is asserted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Cable Detect is released</td>
</tr>
<tr>
<td>irq</td>
<td>Output</td>
<td>1</td>
<td>Interrupt request for CPU. Active-High.</td>
</tr>
<tr>
<td>SB_STATUS_IN_tdata</td>
<td>Input</td>
<td>2</td>
<td>Side Band Status input signals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 0: link_rdy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bit 1: video_rdy</td>
</tr>
<tr>
<td>SB_STATUS_IN_tvalid</td>
<td>Input</td>
<td>1</td>
<td>Side Band Status input valid</td>
</tr>
<tr>
<td>video_rst</td>
<td>Output</td>
<td>1</td>
<td>Video reset signal in video_clk domain. Active-High.</td>
</tr>
</tbody>
</table>

1. The Hot Plug Detect (HPD) signal is driven by an HDMI sink and asserted when the HDMI cable is connected to notify the HDMI source of the presence of an HDMI sink. In most cases, the HDMI sink is simply connected to 5V power signal. Therefore, in the PCB, if you choose to use a voltage divider or level shifter, the HPD polarity remains as Active High. However, if you add a divider to the HPD signal, then the HPD polarity must be set to Active Low in HDMI Transmitter Subsystem GUI. When designing a HDMI sink system using HDMI Receiver Subsystem, in the PCB, if you choose to use a voltage level shifter, the HPD polarity remains as Active High. However, if you choose to add an inverter to the HPD signal, then the HPD polarity must be set to Active Low in HDMI Receiver Subsystem GUI. There are two common ways of using HPD: Toggle HPD to trigger HDCP authentication process (usually 100 ~ 500ms). Or a longer HPD toggle (>1s), the HDMI sink is notifying the source its present without cable unplug and plug. The software API used to assert and release HPD is XV_HdmiRxSs_SetHpd.
2. The Cable Detect signal is connected to a 5V power signal from the HDMI cable connector via some level shifter to notify the HDMI RX Subsystem that a HDMI source is connected.
Clocks and Resets

Table 2-12 provides an overview of the clocks and resets. See Clocking and Resets in Chapter 3 for more information.

Table 2-12: Clocks and Resets

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>s_axi_cpu_aclk</td>
<td>Input</td>
<td>1</td>
<td>AXI4-Lite CPU control interface clock.</td>
</tr>
<tr>
<td>s_axi_cpu_aretn</td>
<td>Input</td>
<td>1</td>
<td>Reset, associated with s_axi_cpu_aclk (active-Low). The s_axi_cpu_aretn signal resets the entire subsystem including the data path and AXI4-Lite registers.</td>
</tr>
<tr>
<td>s_axis_video_aclk</td>
<td>Input</td>
<td>1</td>
<td>AXI4-Stream video output clock.</td>
</tr>
<tr>
<td>s_axis_video_aretn</td>
<td>Input</td>
<td>1</td>
<td>Reset, associated with s_axis_video_aclk (active-Low). Resets the AXI4-Stream data path for the video output.</td>
</tr>
<tr>
<td>s_axis_audio_aclk</td>
<td>Input</td>
<td>1</td>
<td>AXI4-Stream Audio output clock. (The audio streaming clock must be greater than or equal to 128 times the audio sample frequency)</td>
</tr>
<tr>
<td>s_axis_audio_aretn</td>
<td>Input</td>
<td>1</td>
<td>Reset, associated with s_axis_audio_aclk (active-Low). Resets the AXI4-Stream data path for the audio output.</td>
</tr>
<tr>
<td>link_clk</td>
<td>Input</td>
<td>1</td>
<td>HDMI Link data output clock. This connects to the Video PHY Controller Link clock output.</td>
</tr>
<tr>
<td>video_clk</td>
<td>Input</td>
<td>1</td>
<td>Clock for the native video interface.</td>
</tr>
</tbody>
</table>

Notes:
1. The reset should be asserted until the associated clock becomes stable.
Designing with the Subsystem

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

General Design Guidelines

The subsystem connects to other hardware components to construct a complete HDMI RX system. These hardware components usually are different from device to device. For example, Kintex®-7 devices have a different PLL architecture from UltraScale™ devices. Therefore, you need to fully understand the system and adjust the subsystem parameters accordingly. Appendix C, Application Software Development describes how to integrate the subsystem API into a software application.

Audio Data Stream

An AXI4-Stream audio cycle is illustrated in Figure 3-1. The data is valid when both the valid (TVLD) and ready (TRDY) signals are asserted. The HDMI 1.4/2.0 Receiver Subsystem sends out adjacent channels in sequential order (CH0, CH1, etc). Usually, the audio stream receiver also expects the channels in sequential order. If the channel data is not in order, the channel data might be mapped into other channel sample slots.

![Figure 3-1: Audio Cycle](image)

In HDMI 1.4/2.0 Receiver Subsystem, the number of Audio Channels is set through the software driver. You must enable the correct number of audio channel according to your use case and send the corresponding audio channel data mapping to the channel ID (TID). For
example, if you intend to send out 8 channel audio, then you must set Audio Channel number to 8 in HDMI 1.4/2.0 Receiver Subsystem driver. Then, the corresponding audio data must be prepared and sent to HDMI 1.4/2.0 Receiver Subsystem in the hardware, as described in Figure 3-1.

**Video Output Stream Interface**

The AXI4-Stream video interface supports dual or quad pixels per clock with 8 bits, 10 bits, 12 bits and 16 bits per component for RGB and YUV444 color spaces. The color depth in YUV422 color space is always 12-bits per pixel.

When the parameter, **Max Bits Per Component**, is set to 16, Figure 3-2 shows the data format for quad pixels per clock to be fully compliant with the AXI4-Stream video protocol. A data format for a fully compliant AXI4-Stream video protocol dual pixels per clock is illustrated in Figure 3-3.

*Figure 3-2: Quad Pixels Data Format (Max Bits Per Component = 16)*
When the parameter, **Max Bits Per Component**, is set to 12, video formats with actual bits per component larger than 12 is truncated to the Max Bits Per Component. The remaining least significant bits are discarded. If the actual bits per component is smaller than Max Bits Per Component set in the Vivado IDE, all bits are transported with the MSB aligned and the remaining LSB bits are padded with 0. This applies to all **Max Bits Per Component** settings.

As an illustration, when **Max Bits Per Component** is set to 12, **Figure 3-4** shows the data format for quad pixels per clock to be fully compliant with the AXI4-Stream video protocol.

### Figure 3-3: Dual Pixels Data Format (Max Bits Per Component = 16)

When the parameter, **Max Bits Per Component**, is set to 12, video formats with actual bits per component larger than 12 is truncated to the Max Bits Per Component. The remaining least significant bits are discarded. If the actual bits per component is smaller than Max Bits Per Component set in the Vivado IDE, all bits are transported with the MSB aligned and the remaining LSB bits are padded with 0. This applies to all **Max Bits Per Component** settings.

### Table 3-1: Max Bits Per Component Support

<table>
<thead>
<tr>
<th>Max Bits Per Component</th>
<th>Actual Bits Per Component</th>
<th>Bits Transported by Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>8</td>
<td>[7:0]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>[9:0]</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>[11:0]</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>[15:0]</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>[7:0]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>[9:0]</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>[11:0]</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>[15:4]</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>[7:0]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>[9:0]</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>[11:2]</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>[15:6]</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>[7:0]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>[9:2]</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>[15:8]</td>
</tr>
</tbody>
</table>
A data format for a fully compliant AXI4-Stream video protocol with dual pixels per clock is illustrated in Figure 3-5.

The video interface can also transport quad and dual pixels in the YUV420 color space. However the current data format is not compliant with the AXI4-Stream video protocol. Figure 3-6 and Figure 3-7 show the data format for quad and dual pixels formats.
Similarly, for YUV 4:2:0 deep color (10, 12, or 16 bits), the data representation is the same as shown in Figure 3-6 and Figure 3-7. The only difference is that each component carries more bits (10, 12, and 16). To make the YUV 4:2:0 compatible with AXI4-Stream Video IP and System Design Guide [Ref 12], enable it from the HDMI Receiver Subsystem GUI.

Using an 8-bit video as an example, Figure 3-8 illustrates the YUV 4:2:0 AXI4-Stream video data representation in AXI4-Stream Video IP and System Design Guide [Ref 12].

However, in the native HDMI video interface, the video data representation must be as shown in Figure 3-9.
Therefore, a remapping feature is added to HDMI 1.4/2.0 Receiver Subsystem to convert AXI4-Stream video into HDMI native video.

The subsystem provides full flexibility to construct a system using the configuration parameters, maximum bits per component and number of pixels per clock. Set these parameters so that the video clock and link clock are supported by the targeted device. For example, when dual pixels per clock is selected, the AXI4-Stream video need to run at higher clock rate comparing with quad pixels per clock design. In this case, it is more difficult for the system to meeting timing requirements. Therefore the quad pixels per clock data mapping is recommended for design intended to send higher video resolutions.

Some video resolutions (for example, 720p60) have horizontal timing parameters (1650) which are not a multiple of 4. In this case the dual pixels per clock data mapping must be chosen.

For more information on the video AXI4-Stream interface and video data format, see the AXI4-Stream Video IP and System Design Guide (UG934) [Ref 12].

Clocking

The S_AXI_CPU_IN, VIDEO_IN, and AUDIO_IN can be run at their own clock rate. The HDMI link interfaces and native video interface also run at their own clock rate. Therefore, five separate clock interfaces are provided called s_axi_cpu_aclk, s_axis_video_aclk, s_axis_audio_aclk, link_clk, and video_clk respectively.

The audio streaming clock must be greater than or equal to 128 times the audio sample frequency. Because audio clock regeneration is not part of the HDMI RX subsystem, you must provide an audio clock to the application. This can be achieved by using an internal PLL or external clock source.

IMPORTANT: The AXI4-Lite CPU clock must run at 100 Mhz.
The HDMI clock structure is illustrated in Figure 3-10 and Table 3-2.

![Figure 3-10: HDMI Clocking Structure](image_url)

### Table 3-2: Clocking

<table>
<thead>
<tr>
<th>Clock</th>
<th>Function</th>
<th>Freq/Rate</th>
<th>Example (1)</th>
</tr>
</thead>
</table>
| TMDS clock   | Source synchronous clock to HDMI interface (This is the actual clock on the HDMI cable). | = 1/10 data rate (for data rates < 3.4 Gb/s) | Data rate = 2.97 Gb/s  
               |                                                                            | = 1/40 data rate (for data rates > 3.4 Gb/s) | TMDS clock = 2.97/10 = 297 MHz  
               |                                                                            |                                  | Data rate = 5.94 Gb/s  
               |                                                                            |                                  | TMDS clock = 5.94/40 = 148.5 MHz |
| Data clock   | This is the actual data rate clock. This clock is not used in the system. It is only listed to illustrate the clock relations. | = TMDS clock (for data rates < 3.4 Gb/s) | Data rate = 2.97 Gb/s  
               |                                                                            | = TMDS clock * 4 (for data rates > 3.4 Gb/s) | Data clock = TMDS clock * 4 = 594 MHz  
               |                                                                            |                                  | TMDS clock = 148.5 MHz |
| Link clock   | Clock used for data interface between HDMI PHY Layer Module and subsystem | = 1/4 of data clock | TMDS clock = 297 MHz  
               |                                                                            |                                  | Data clock = 297 MHz  
               |                                                                            |                                  | Link clock = 297 MHz/4 = 74.25 MHz |
               |                                                                            |                                  | Data clock = 594 MHz  
               |                                                                            |                                  | Link clock = 594 MHz/4 = 148.5 MHz |
Chapter 3: Designing with the Subsystem

Table 3-2: Clocking (Cont’d)

<table>
<thead>
<tr>
<th>HDMI Clocking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock</td>
</tr>
<tr>
<td>Pixel clock</td>
</tr>
<tr>
<td>Video clock</td>
</tr>
</tbody>
</table>

Notes:
1. The examples in the Example column are only for reference and do not cover all the possible resolutions. Each GT has its own hardware requirements and limitations. Therefore, to use the HDMI 1.4/2.0 Receiver Subsystem with different GT devices, calculate the clock frequencies and make sure the targeted device is able to support it. When using the HDMI 1.4/2.0 Receiver Subsystem with Xilinx Video PHY Controller IP core, more information can be found in Video PHY Controller LogiCORE IP Product Guide (PG230) [Ref 22].

For example, 1080p60, 12BPC, and 2PPC are used to show how all the clocks are derived.

<table>
<thead>
<tr>
<th>Video Resolution</th>
<th>Horizontal Total</th>
<th>Horizontal Active</th>
<th>Vertical Total</th>
<th>Vertical Active</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1080p60</td>
<td>2200</td>
<td>1920</td>
<td>1125</td>
<td>1080</td>
<td>60</td>
</tr>
</tbody>
</table>

Pixel clock represents the total number of pixels need to be sent every second. Therefore,

\[
\text{Pixel clock} = H_{\text{total}} \times V_{\text{total}} \times \text{Frame Rate} \\
= 2200 \times 1125 \times 60 \\
= 148,500,000 \\
= 148.5\text{Mhz}
\]

\[
\text{Link clock} = (\text{Data clock})/4 = 222.75/4 = 55.6875\text{Mhz}
\]

\[
\text{Video clock} = (\text{Pixel clock})/\text{PPC} = 148.5/2 = 74.25\text{Mhz}
\]

\[
\text{Data clock} = \text{Pixel clock} \times \text{BPC}/8 = 148.5 \times 12/8 = 222.75\text{Mhz}
\]

Using the associative property in this example,
Data clock = 222.75Mhz < 340Mhz

then

TMDS clock = Data clock = 222.75Mhz

---

**Resets**

Each AXI input interface has its own reset signal. The reset signals, `s_axi_cpu_arsetn`, `s_axis_video_arsetn` and `s_axis_audio_arsetn` are for `S_AXI_CPU_IN`, `VIDEO_IN` (AXI4-Stream Video Interface), and `AUDIO_IN` respectively. These three reset signals are active-Low. Because the reset signal is used across multiple sub-blocks in the subsystem, keep the system in the reset state until all the clocks are stabilized. You can use the `locked` signal from the clock generation block as a reset signal.

*Note:* There is no dedicated hardware reset for VIDEO_OUT interface when Native Video interface is selected. However, HDMI RX Subsystem outputs a `video_rst` signal, which you can use to reset its supporting Native Video processing modules.
Chapter 4

Design Flow Steps

This chapter describes customizing and generating the subsystem, constraining the subsystem, and the simulation, synthesis and implementation steps that are specific to this IP subsystem. More detailed information about the standard Vivado® design flows and the IP integrator can be found in the following Vivado Design Suite user guides:

- Vivado Design Suite User Guide: Designing IP Subsystems using IP Integrator (UG994) [Ref 13]
- Vivado Design Suite User Guide: Designing with IP (UG896) [Ref 14]
- Vivado Design Suite User Guide: Getting Started (UG910) [Ref 15]
- Vivado Design Suite User Guide: Logic Simulation (UG900) [Ref 16]

Customizing and Generating the Subsystem

This section includes information about using Xilinx tools to customize and generate the subsystem in the Vivado Design Suite.

The HDMI 1.4/2.0 Receiver Subsystem can be added to a Vivado IP integrator block design in the Vivado Design Suite and can be customized using IP catalog. For more detailed information on customizing and generating the subsystem in the Vivado IP integrator, see the Vivado Design Suite User Guide: Designing IP Subsystems using IP Integrator (UG994) [Ref 13]. IP integrator might auto-compute certain configuration values when validating or generating the design. To check whether the values do change, see the description of the parameter in this chapter. To view the parameter value, run the validate_bd_design command in the Tcl Console.

You can customize the subsystem for use in your design by specifying values for the various parameters associated with the IP subsystem using the following steps:

1. In the Flow Navigator, click on Create Block Diagram or Open Block Design under the IP Integrator heading.
2. Right click in the diagram and select Add IP.

A searchable IP catalog opens. You can also add IP by clicking on the Add IP button on the left side of the IP Integrator Block Design canvas.
3. Click on the IP name and press the Enter key on your keyboard or double click on the IP name.

4. Double-click the selected IP block or select the **Customize Block** command from the right-click menu.

For details, see the *Vivado Design Suite User Guide: Designing with IP* (UG896) [Ref 14] and the *Vivado Design Suite User Guide: Getting Started* (UG910) [Ref 15].

**Note:** Figures in this chapter are illustrations of the Vivado Integrated Design Environment (IDE). The layout depicted here might vary from the current version.

**Top Level Tab**

The Top level tab is shown in *Figure 4-1*.
Chapter 4: Design Flow Steps

The parameters on the Top level tab are as follows:

**Component Name**: The component name is set automatically by IP Integrator.

**Video Interface**: This option selects the Video Interface for the HDMI RX subsystem. The allowable options are **AXIS-Stream** or **Native Video**.

**Include HDCP 1.4 Decryption**: This option enables HDCP 1.4 decryption.

**Include HDCP 2.2 Decryption**: This option enables HDCP 2.2 decryption.

**Max bits per component**: This option selects the maximum bits per component. The allowable options are, 8, 10, 12 or 16 bits. This parameter is to set the maximum “allowed” bits per component, and the actual bits per component can be set from the software API to a different value. However, the actual bits per component is bounded by the **Max bits per component**. For example, if the **Max bits per component** is set to 16, the user can set the actual bits per component from the software API to any of the values, 8, 10, 12 or 16. But if the **Max bits per component** is set to 8, you can only set the actual bits per component to 8 through the software API.

**Number of pixels per clock on Video Interface**: This option selects the number of pixels per clock. The allowable options are 2 or 4 pixels.

**IMPORTANT**: Pixels per clock (PPC) can only be selected at IP generation time, and must remain static in the design. Some video format with a total horizontal resolution that is NOT divisible by 4 (for example, 720p60 has a total horizontal pixel of 1650, which is not divisible by 4) are not supported. If the design is intended to support this kind of video formats, ensure that **PPC=2** is selected in Vivado.

**Video over AXIS compliant NTSC/PAL Support**: This option enables the HDMI RX subsystem to support Video over AXIS compliant NTSC/PAL.

- A pixel repetition of 2 is supported by current hardware
- 480i60 and 576i50 resolutions are supported in current software.

**Video over AXIS compliant YUV420 Support**: This option enables the HDMI RX subsystem to support Video over AXIS compliant YUV420.

**Hot Plug Detect Active**: This option selects the HPD active polarity. The allowable options are High or Low.

**EDID RAM size**: The allowable options are, 256, 512, 1024 or 4096.

**Cable Detect Active**: This option selects the Cable Detect active polarity. The allowable options are High or Low.
Video Bridge Tab (Video AXI4 Stream Interface Only)

The Video Bridge tab is shown in Figure 4-2.

![Figure 4-2: Video Bridge Tab](image)

The parameter on the Video Bridge tab is as follows:

**FIFO Depth**: Specifies the number of locations in the input FIFO. The allowable values are 32, 1024, 2048, 4096, and 8192.
Native Video Interface Option

The native video interface option window is shown in Figure 4-3.

**Include HDCP 1.4 Decryption**: This option enables HDCP 1.4 decryption.

**Include HDCP 2.2 Decryption**: This option enables HDCP 2.2 decryption.

**Note**: HDCP 1.4 and 2.2 Decryption options are only configurable if you have a HDCP license, else it is disabled.
The Top level tab without a valid HDCP license is shown in **Figure 4-4**.

![Top level tab (No HDCP License)](image)

**Figure 4-4: Top level Tab (No HDCP License)**

**User Parameters**

**Table 4-1** shows the relationship between the fields in the Vivado IDE and the User Parameters (which can be viewed in the Tcl Console).

**Table 4-1: Vivado IDE Parameter to User Parameter Relationship**

<table>
<thead>
<tr>
<th>Vivado IDE Parameter/Value</th>
<th>User Parameter/Value</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video Interface</td>
<td>C_VID_INTERFACE</td>
<td>AXI4-Stream</td>
</tr>
<tr>
<td>AXI4-Stream</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Native Video</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Include HDCP 1.4 Decryption</td>
<td>C_INCLUDE_HDCP_1_4</td>
<td>Exclude</td>
</tr>
<tr>
<td>Exclude (Untick)</td>
<td>FALSE</td>
<td></td>
</tr>
<tr>
<td>Include (Tick)</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td>Vivado IDE Parameter/Value</td>
<td>User Parameter/Value</td>
<td>Default Value</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Include HDCP 2.2 Decryption</td>
<td>C_INCLUDE_HDCP_2_2</td>
<td>Exclude</td>
</tr>
<tr>
<td>Exclude (Untick)</td>
<td>FALSE</td>
<td></td>
</tr>
<tr>
<td>Include (Tick)</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td>Video over AXIS compliant NTSC/PAL Support</td>
<td>C_INCLUDE_LOW_RESO_VID</td>
<td>Exclude</td>
</tr>
<tr>
<td>Exclude (Untick)</td>
<td>FALSE</td>
<td></td>
</tr>
<tr>
<td>Include (Tick)</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td>Video over AXIS compliant YUV420 Support</td>
<td>C_INCLUDE_YUV420_SUP</td>
<td>Exclude</td>
</tr>
<tr>
<td>Exclude (Untick)</td>
<td>FALSE</td>
<td></td>
</tr>
<tr>
<td>Include (Tick)</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td>Max bits per component</td>
<td>C_MAX_BITS_PER_COMPONENT</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Number of pixels per clock on Video Interface</td>
<td>C_INPUT_PIXELS_PER_CLOCK</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Hot Plug Detect Active</td>
<td>C_HPD_INVERT</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Cable Detect Active</td>
<td>C_CD_INVERT</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>EDID RAM Size</td>
<td>C_EDID_RAM_SIZE</td>
<td>256</td>
</tr>
<tr>
<td>256</td>
<td>256</td>
<td></td>
</tr>
<tr>
<td>512</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>1024</td>
<td>1024</td>
<td></td>
</tr>
<tr>
<td>4096</td>
<td>4096</td>
<td></td>
</tr>
<tr>
<td><strong>Video Bridge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FIFO Depth</td>
<td>C_ADDR_WIDTH</td>
<td>1024</td>
</tr>
<tr>
<td>32</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>1024</td>
<td>1024</td>
<td></td>
</tr>
<tr>
<td>2048</td>
<td>2048</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 4: Design Flow Steps

Output Generation

For details, see the *Vivado Design Suite User Guide: Designing with IP* (UG896) [Ref 14].

Constraining the Subsystem

This section contains information about constraining the subsystem in the Vivado Design Suite.

Required Constraints

There are clock frequency constraints for the `s_axi_cpu_aclk`, `s_axis_video_aclk`, `s_axis_audio_aclk`, `link_clk`, and `video_clk`. For example,

```
create_clock -name s_axi_cpu_aclk -period 10.0 [get_ports s_axi_cpu_aclk]
create_clock -name s_axis_audio_aclk -period 10.0 [get_ports s_axis_audio_aclk]
create_clock -name link_clk -period 13.468 [get_ports link_clk]
create_clock -name video_clk -period 6.734 [get_ports video_clk]
create_clock -name s_axis_video_aclk -period 5.0 [get_ports s_axis_video_aclk]
```

When using this subsystem in the Vivado® Design Suite flow with Video PHY Controller modules, `link_clk` and `video_clk` are generated from the Video PHY Controller. Therefore, the clock constraints are set to the Video PHY Controller constraints instead of these generated clocks. See Clocking in the *Video PHY Controller LogiCORE™ IP Product Guide* (PG230) [Ref 22] for more information.

`s_axi_cpu_aclk`, `s_axis_video_aclk`, and `s_axis_audio_aclk` constraints are generated at system-level, for example by using a clock wizard.

<table>
<thead>
<tr>
<th>Vivado IDE Parameter/Value</th>
<th>User Parameter/Value</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096</td>
<td>4096</td>
<td></td>
</tr>
<tr>
<td>8192</td>
<td>8192</td>
<td></td>
</tr>
</tbody>
</table>
Device, Package, and Speed Grade Selections

For more information on the device constraint/dependency, see the Video PHY Controller LogiCORE IP Product Guide (PG230) [Ref 22].

Table 4-2 shows the device and speed grade selections for HDMI 1.4/2.0 Receiver Subsystem.

Table 4-2: Device and Speed Grade Selections

<table>
<thead>
<tr>
<th>Device Family</th>
<th>PPC</th>
<th>2</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BPC</td>
<td>8</td>
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<tr>
<td>Speed Grade</td>
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<td></td>
<td></td>
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<td>Artix-7</td>
<td>–1</td>
<td>HDMI 1.4(1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–2</td>
<td>HDMI 1.4(1)</td>
<td></td>
</tr>
<tr>
<td>Kintex-7</td>
<td>–1</td>
<td>HDMI 1.4(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–2</td>
<td>HDMI 2.0(1)</td>
<td></td>
</tr>
<tr>
<td>Kintex UltraScale</td>
<td>–1</td>
<td>HDMI 2.0(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–2</td>
<td>HDMI 2.0(2)</td>
<td></td>
</tr>
<tr>
<td>Virtex-7</td>
<td>–1</td>
<td>HDMI 1.4(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–2</td>
<td>HDMI 2.0(1)</td>
<td></td>
</tr>
<tr>
<td>Virtex UltraScale</td>
<td>–1</td>
<td>HDMI 2.0(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–2</td>
<td>HDMI 2.0(2)</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. All HDMI 1.4 resolutions can be supported.
2. Full HDMI 2.0 resolutions support up to 4096 x 2160 @ 60fps.

Clock Frequencies

The AXI4-Lite CPU clock must run at 100 Mhz. See Clocking in Chapter 3 for more information.

Clock Management

This section is not applicable for this IP subsystem.

Clock Placement

This section is not applicable for this IP subsystem.
Banking

This section is not applicable for this IP subsystem.

Transceiver Placement

This section is not applicable for this IP subsystem.

I/O Standard and Placement

This section is not applicable for this IP subsystem.

Simulation

Simulation of the subsystem is not supported.

Synthesis and Implementation

For details about synthesis and implementation, see the *Vivado Design Suite User Guide: Designing with IP* (UG896) [Ref 14].
Example Design

This chapter contains step-by-step instructions for generating an HDMI Example Design from the HDMI 1.4/2.0 Receiver Subsystem by using Vivado® Flow.

Running the Example Design

1. Open the Vivado Design Suite and create a new project.
2. In the pop-up window, press **Next** 5 times.
3. Select the Board. (KC705, ZC706, and KCU105 are supported.)
4. Click \textbf{Finish}.
5. Click **IP Catalog** and select HDMI 1.4/2.0 Receiver Subsystem under Video Connectivity, then double click on it.

- For the Example Design flow, Native Video Interface is not supported.
- You can rename the IP component name, which is used as example design project name.

6. Configure HDMI 1.4/2.0 Receiver Subsystem, then click **OK**.
The Generate Output Products dialog box appears.

7. Click on **Generate**.
   a. You may optionally click **Skip** if you just want to generate the example design.
8. Right click on the HDMI 1.4/2.0 Receiver Subsystem component under Design source, and click **Open IP Example Design**.
9. Choose the target project location, then click **OK**.

The IPI Design is then generated. You may choose to Run Synthesis, Implementation, or Generate Bitstream.
Chapter 5: Example Design

An overall system IPI block diagram of the KC705 based example design is shown below.
10. Export Hardware to prepare for SDK Example Design Flow.

11. Click **OK**. (Use the default Export Location <Local to Project> for the example design.)

12. Launch SDK.
13. Choose SDK workspace location. By default, it is "Local to Project."

Vivado SDK is launched.

15. Enter BSP project name and click **Finish**.

16. Click **OK**.
17. Find the HDMI 1.4/2.0 Receiver Subsystem and click on **Import Examples**.
18. Select xhdti_example.

For project generated for KC705 and KCU105 boards (MicroBlaze™ soft processor core based), select **xhdti_example**.

For project generated for ZC706 boards (Zynq®-7000 SoC ARM processor based), select **xhdti_example_zynq**.
Chapter 5: Example Design

The example application is built successfully. The .elf is ready to use.

Running the Reference Design (KC705)

Use the following steps to execute the system using generated bitstream and software elf from the example design:

1. Launch the Xilinx System Debugger by selecting Start > All Programs > Xilinx Design Tools > Vivado 2017.1 > Vivado 2017.1 Tcl Shell.

2. In the Xilinx command shell window, change to the Example Design Project directory:

   `Vivado% cd ./v_hdmi_rx_ss_0_ex`

3. Invoke Xilinx System Debugger (xsdb).

   `Vivado% xsdb`

4. Establish connections to debug targets.

   `xsdb% connect`

5. Download the bitstream to the FPGA:

   `xsdb% fpga -file ./v_hdmi_rx_ss_0_ex.runs/impl_1/exdes_wrapper.bit`
Chapter 5: Example Design

6. Set the target processor.

```bash
xsdb% target -set 3
```

7. Download the software .elf to the FPGA.

```bash
xsdb% dow ./v_hdmi_rx_ss_0_ex.sdk/<name of bsp>_xhdmi_example_1/
    Debug/<name of bsp>_xhdmi_example_1.elf
```

8. Run the software.

```bash
xsdb% stop
xsdb% rst
xsdb% con
```

9. Exit the XSDB command prompt.

```bash
xsdb% exit
```

**IMPORTANT:** When using the TB-FMCH-HDMI4K example design with the KCU105 board, you must set the FMC VADJ_1V8 Power Rail before programming the FPGA with bitstream generated from Example Design Flow. KCU105 Board FMCH VADJ Adjustment shows the steps on how to set the VADJ power rail when using KCU105 board. For more details about KCU105 Board, to KCU105 Board User Guide [Ref 18].

---

**KCU105 Board FMCH VADJ Adjustment**

The KCU105 board system controller must apply power to the VADJ power rail for the HDMI 2.0 FMC card (TB-FMCH-HDMI4K). Most new boards are per-programmed and should be detected. The VADJ is powered when the DS19 LED (located near the power switch on the KCU105 board) is ON.

If an older version KCU105 board is used, or the board is not properly programmed upon receiving, you must manually set the VADJ power rail to 1.8V for the HDMI 2.0 FMC card prior to bitstream configuration.

Perform these steps to set the VADJ power rail through the UART terminal are:

1. Connect a USB cable between the USB UART connector of the KCU105 board and a PC running Windows.

2. Use the Windows Device Manager to determine which virtual COM port is assigned to the UART for the Zynq-7000 AP SoC system controller and which is assigned to the UART for the UltraScale FPGA. In the list of COM ports in the Device Manager window, the enhanced COM port associated with the CP210x, is the one connected to the KCU105 board system controller and the standard COM port is the one connected to the FPGA UART.
3. Open a terminal window (115200, 8, N, 1) and set the COM port to the one communicating with the KCU105 board system controller.

4. After the UART terminal is connected, power cycle the KCU105 board to refresh the system controller menu in the UART terminal. Select this option in the system controller menu:
   a. Adjust FPGA Mezzanine Card (FMC) Settings.

5. In the next menu, select:
   a. Set FMC VADJ to 1.8V.

**Migration Notes**

When migrating from version 2016.3 or earlier, make note of the following:

- Hot Plug Detect Active has been added to HDMI 1.4/2.0 Transmitter Subsystem GUI.
  Choose High in the Example Design (according to board design).

- Hot Plug Detect Active has been added to HDMI 1.4/2.0 Receiver Subsystem GUI.
  Choose Low in Example Design (according to board design).

- Cable Detect Active has been added to HDMI 1.4/2.0 Receiver Subsystem GUI.
  Choose Low in Example Design (according to board design).

- HDCP 1.4/2.2 is enabled by default in Example Design application software.
  Removed UART option to Enable HDCP 1.4 or HDCP 2.2.

- Auto switching has been added to the Example Design Application software.
  You do not need to choose HDCP 1.4 or HDCP 2.2 from UART. A corresponding HDCP is selected according to the capability of connected source/sink. If the device support both HDCP 1.4 and HDCP 2.2, the priority is given to HDCP 2.2.

- HDCP repeater feature has been added.
  You can enabled/disable it by selecting "h" from UART menu.

- System log is moved from direct UART printout to event log.
  You can display the event log by selecting "z" from UART menu.
Appendix A

Verification, Compliance, and Interoperability

Interoperability

Interoperability tests for the HDMI 1.4/2.0 Receiver Subsystem have been conducted with the following hardware setup.

Hardware Testing

The HDMI 1.4/2.0 Receiver Subsystem has been validated using

- Kintex®-7 FPGA Evaluation Kit (KC705)
- Kintex® UltraScale™ FPGA Evaluation Kit (KCU105)
- Inrevium Artix-7 FPGA ACDC A7 Evaluation Board
- Zynq®-7000 All Programmable SoC evaluation board (ZC706)

This release is tested with the following source devices:

- Quantum Data 980B
- Quantum Data 780B
- Apple TV (Gen 2/3/4)
- Android M8 media player
- Apple MacBook Pro
- Google Chromecast
- Open Hour media box
- Dell Latitude laptop (E7240)
- Intel HD Graphics 4000
- Nvidia GTX970 graphics card
Video Resolutions

Figure A-1 shows the hardware setup for AXI4-Stream Video Interface. An HDMI source connects to Video PHY Controller, which converts the HDMI Video into LINK DATA and sends to the HDMI RX Subsystem. Then, the HDMI RX Subsystem translates the LINK DATA into AXI4-Stream Video and sends to the Test Pattern Generator. By setting the Test Pattern Generator to pass-through mode, the AXI4-Stream Video from the HDMI RX Subsystem is passed to HDMI TX Subsystem where it gets translated to LINK DATA again and sends back to the Video PHY Controller. The Video PHY Controller then converts it back to HDMI Video and sends to HDMI Sink.
For Video PHY Controller settings and PLL selections, see the Video PHY Controller LogiCORE IP Product Guide (PG230) [Ref 22].

Similarly, Figure A-2 shows the hardware setup for Native Video Interface. The only difference is that two Video Bridge modules are added in between the HDMI RX Subsystem and the Test Pattern Generator, and between the Test Pattern Generator to the HDMI TX Subsystem.
Table A-1, Table A-2, and Table A-3 show the video resolutions that were tested as part of the release for different video formats.

Table A-1: Tested Video Resolutions for RGB 4:4:4 and YCbCr 4:4:4

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Active</td>
<td>Total</td>
</tr>
<tr>
<td>480i60</td>
<td>858</td>
<td>720</td>
<td>525</td>
</tr>
<tr>
<td>576i50</td>
<td>864</td>
<td>720</td>
<td>625</td>
</tr>
<tr>
<td>1080i50</td>
<td>2640</td>
<td>1920</td>
<td>1125</td>
</tr>
<tr>
<td>1080i60</td>
<td>2200</td>
<td>1920</td>
<td>1125</td>
</tr>
<tr>
<td>480p60</td>
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<td>720</td>
<td>525</td>
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<tr>
<td>576p50</td>
<td>864</td>
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<td>625</td>
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<td>720p50</td>
<td>1980</td>
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<td>750</td>
</tr>
<tr>
<td>720p60</td>
<td>1650</td>
<td>1280</td>
<td>750</td>
</tr>
<tr>
<td>1080p24</td>
<td>2750</td>
<td>1920</td>
<td>1125</td>
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<td>1080p25</td>
<td>2640</td>
<td>1920</td>
<td>1125</td>
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<tr>
<td>1080p30</td>
<td>2200</td>
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<td>1125</td>
</tr>
<tr>
<td>1080p50</td>
<td>2640</td>
<td>1920</td>
<td>1125</td>
</tr>
</tbody>
</table>
Appendix A: Verification, Compliance, and Interoperability

Table A-1: Tested Video Resolutions for RGB 4:4:4 and YCbCr 4:4:4 (Cont’d)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Active</td>
<td>Total</td>
</tr>
<tr>
<td>1080p60</td>
<td>2200</td>
<td>1920</td>
<td>1125</td>
</tr>
<tr>
<td>1080p120</td>
<td>2200</td>
<td>1920</td>
<td>1125</td>
</tr>
<tr>
<td>2160p24</td>
<td>5500</td>
<td>3840</td>
<td>2250</td>
</tr>
<tr>
<td>2160p25</td>
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<td>2160p30</td>
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<td>2250</td>
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<td>525</td>
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<td>800</td>
<td>628</td>
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<td>790</td>
</tr>
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<td>1792</td>
<td>1366</td>
<td>798</td>
</tr>
<tr>
<td>ugap60</td>
<td>2160</td>
<td>1600</td>
<td>1250</td>
</tr>
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<td>wxugap60</td>
<td>2592</td>
<td>1920</td>
<td>1245</td>
</tr>
<tr>
<td>wsgap60</td>
<td>2240</td>
<td>1680</td>
<td>1089</td>
</tr>
</tbody>
</table>

Notes:
1. Not all resolutions can be supported due to VPHY limitation. For details, refer to Video PHY Controller LogiCORE IP Product Guide (PG230) [Ref 22].
2. In this release, UXGA 60 Hz is supported in the HDMI 1.4/2.0 Receiver Subsystem for 8, 10, and 12 bits per component only.

Table A-2: Tested Video Resolutions for YCbCr 4:2:2 at 12 Bits/component

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Active</td>
<td>Total</td>
</tr>
<tr>
<td>1080i50</td>
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<td>1920</td>
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</tr>
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<td>1080i60</td>
<td>2200</td>
<td>1920</td>
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</tr>
<tr>
<td>480p60</td>
<td>858</td>
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<td>525</td>
</tr>
<tr>
<td>576p50</td>
<td>864</td>
<td>720</td>
<td>625</td>
</tr>
<tr>
<td>720p50</td>
<td>1980</td>
<td>1280</td>
<td>750</td>
</tr>
<tr>
<td>720p60</td>
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<td>2750</td>
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<td>1125</td>
</tr>
<tr>
<td>1080p50</td>
<td>2640</td>
<td>1920</td>
<td>1125</td>
</tr>
</tbody>
</table>
### Appendix A: Verification, Compliance, and Interoperability

#### Table A-2: Tested Video Resolutions for YCbCr 4:2:0 at 12 Bits/component

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Active</td>
<td>Total</td>
</tr>
<tr>
<td>1080p60</td>
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<td>2160p24</td>
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<td>2160p25</td>
<td>5280</td>
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<td>2250</td>
</tr>
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<td>525</td>
</tr>
<tr>
<td>svgap60</td>
<td>1056</td>
<td>800</td>
<td>628</td>
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<td>wgap60</td>
<td>1440</td>
<td>1280</td>
<td>790</td>
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<tr>
<td>wxga+p60</td>
<td>1792</td>
<td>1366</td>
<td>798</td>
</tr>
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<td>2160</td>
<td>1600</td>
<td>1250</td>
</tr>
<tr>
<td>wu60p60</td>
<td>2592</td>
<td>1920</td>
<td>1245</td>
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<tr>
<td>wxs60p60</td>
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<td>1680</td>
<td>1089</td>
</tr>
</tbody>
</table>

#### Table A-3: Tested Video Resolutions for YCbCr 4:2:2 at 12 Bits/component

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Frame Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Active</td>
<td>Total</td>
</tr>
<tr>
<td>2160p60</td>
<td>4400</td>
<td>3840</td>
<td>2250</td>
</tr>
</tbody>
</table>
Appendix B

Debugging

This appendix includes details about resources available on the Xilinx Support website and debugging tools.

**TIP:** If the IP generation halts with an error, there might be a license issue. See License Checkers in Chapter 1 for more details.

---

Finding Help on Xilinx.com

To help in the design and debug process when using the HDMI 1.4/2.0 Receiver Subsystem, the Xilinx Support web page contains key resources such as product documentation, release notes, answer records, information about known issues, and links for obtaining further product support.

**Documentation**

This product guide is the main document associated with the HDMI 1.4/2.0 Receiver Subsystem. This guide, along with documentation related to all products that aid in the design process, can be found on the Xilinx Support web page or by using the Xilinx Documentation Navigator.

Download the Xilinx Documentation Navigator from the Downloads page. For more information about this tool and the features available, open the online help after installation.

**Answer Records**

Answer Records include information about commonly encountered problems, helpful information on how to resolve these problems, and any known issues with a Xilinx product. Answer Records are created and maintained daily ensuring that users have access to the most accurate information available.
Answer Records for this subsystem can be located by using the Search Support box on the main Xilinx support web page. To maximize your search results, use proper keywords such as

- Product name
- Tool message(s)
- Summary of the issue encountered

A filter search is available after results are returned to further target the results.

Master Answer Record for the HDMI 1.4/2.0 Receiver Subsystem

AR: 54546

Technical Support

Xilinx provides technical support at the Xilinx Support web page for this LogiCORE™ IP product when used as described in the product documentation. Xilinx cannot guarantee timing, functionality, or support if you do any of the following:

- Implement the solution in devices that are not defined in the documentation.
- Customize the solution beyond that allowed in the product documentation.
- Change any section of the design labeled DO NOT MODIFY.

To contact Xilinx Technical Support, navigate to the Xilinx Support web page.

---

Debug Tools

Tools are available to address HDMI 1.4/2.0 Receiver Subsystem design issues. It is important to know which tools are useful for debugging various situations.

Vivado Design Suite Debug Feature

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

The Vivado logic analyzer is used with the logic debug IP cores, including:

- ILA 2.0 (and later versions)
- VIO 2.0 (and later versions)
Appendix B: Debugging

See the Vivado Design Suite User Guide: Programming and Debugging (UG908) [Ref 19].

Reference Boards

Various Xilinx development boards support the HDMI 1.4/2.0 Receiver Subsystem. These boards can be used to prototype designs and establish that the subsystem can communicate with the system.

- 7 series FPGA evaluation board
  - KC705
- UltraScale FPGA evaluation board
  - KCU105
- Zynq-7000 All Programmable SoC evaluation board
  - ZC706

Hardware Debug

Hardware issues can range from link bring-up to problems seen after hours of testing. This section provides debug steps for common issues. The Vivado debug feature is a valuable resource to use in hardware debug. The signal names mentioned in the following individual sections can be probed using the debug feature for debugging the specific problems.

General Checks

- Ensure that all the timing constraints and all other constraints were met during implementation.
- Ensure that all clock sources are active and clean.
- If using MMCMs in the design, ensure that all MMCMs have obtained lock by monitoring the locked port.
- If your outputs go to 0, check your licensing.
  - User LEDs (KC705/KCU105/ZC706)
  - LED0 - HDMI TX subsystem lock (when HDMI Example Design is used)
Interface Debug

AXI4-Lite Interfaces

Read from a register that does not have all 0s as a default to verify that the interface is functional. Output s_axi_arready asserts when the read address is valid, and output s_axi_rvalid asserts when the read data/response is valid. If the interface is unresponsive, ensure that the following conditions are met:

- The s_axi_aclk and aclk inputs are connected and toggling.
- The interface is not being held in reset, and s_axi_arreset is an active-Low reset.
- The interface is enabled, and s_axi_aclken is active-High (if used).
- The main subsystem clocks are toggling and that the enables are also asserted.

AXI4-Stream Interfaces

If data is not being transmitted or received, check the following conditions:

- If transmit <interface_name>_tready is stuck Low following the <interface_name>_tvalid input being asserted, the subsystem cannot send data.
- If the receive <interface_name>_tvalid is stuck Low, the subsystem is not receiving data.
- Check that the aclk inputs are connected and toggling.
- Check that the AXI4-Stream waveforms are being followed.
- Check subsystem configuration.
Application Software Development

Device Drivers

The HDMI 1.4/2.0 Receiver Subsystem driver abstracts the included supporting elements and provides you with an API for control. The API can be easily integrated into your application thereby providing an out-of-the-box solution.

The subsystem driver is a bare-metal driver, which provides an abstracted view of the feature set provided by each sub-core. It dynamically manages the data and control flow through the processing elements, based on the input/output stream configuration set at run time. Internally, it relies on sub-core drivers to configure the sub-core IP blocks.

Architecture

The subsystem driver provides an easy-to-use, well-defined API to help integrate the subsystem in an application without having to understand the underlying complexity of configuring each and every sub-core.

The subsystem driver consists of the following:

- **Subsystem layer**: Queries exported hardware to determine the subsystem hardware configuration and pull-in sub-core drivers, at build time. It abstracts sub-core drivers, which interface with hardware at register level, into a set of functional APIs. The subsystem driver uses these APIs to dynamically manage the data flow through processing elements.

- **Sub-core drivers**: Every included sub-core has a driver associated with it that provides APIs to interface with the core hardware.

*Figure C-1* shows the HDMI 1.4/2.0 Receiver Subsystem architecture.
The HDMI 1.4/2.0 Receiver Subsystem is a MAC subsystem which works with a Video PHY Controller (PHY) to create a video connectivity system. The HDMI 1.4/2.0 Receiver Subsystem is tightly coupled with the Xilinx Video PHY Controller, which itself is independent and offer flexible architecture with multiple-protocol support. Both MAC and PHY are dynamically programmable through the AXI4-Lite interface.

![Subsystem Driver Architecture](image1)

**Figure C-1: Subsystem Driver Architecture**

![MAC Interfaces with PHY](image2)

**Figure C-2: MAC Interfaces with PHY**
Usage

The HDMI 1.4/2.0 Receiver Subsystem provides a set of API functions for application code to use. On top of that, when HDMI 1.4/2.0 Receiver Subsystem hardware interrupts are generated, the subsystem driver is invoked to configure the system accordingly. HDMI 1.4/2.0 Receiver Subsystem provides callback structure to hook up your own callback functions.

Ensure that the video stream has started. Then, valid AUX data and audio data can be inserted after the video is locked. However, because the application knows what video format will be sent and what audio format will be embedded. With this information, the ACR number can be calculated and set before audio stream is ready to be sent.

In the following sections, only HDMI related modules are covered. The user application needs to take care of system peripheral, such as timer, UART, external system clock generator, etc.

Application Integration

Figure C-3 shows an example code on how an HDMI 1.4/2.0 Receiver Subsystem can be used in your application.
To integrate and use the HDMI 1.4/2.0 Receiver Subsystem driver in your application, the following steps must be followed:

1. Include the subsystem header file `xv_hdmirxss.h` that defines the subsystem object.

2. Provide the storage for a subsystem driver instance in your application code. For example:

   ```c
   XV_HdmiRxSs HdmiRxSs;
   XV_HdmiRxSs_Config *XV_HdmiRxSs_ConfigPtr;
   ```

3. In the subsystem driver instance, there is a metadata structure to store the subsystem hardware configuration. Declare a pointer variable in the application code to point to the instance:

   ```c
   XV_HdmiRxSs_Config *XV_HdmiRxSs_ConfigPtr;
   ```

4. Set EDID parameter for HDMI 1.4/2.0 Receiver Subsystem Subsystem.
void XV_HdmiRxSs_SetEdidParam(XV_HdmiRxSs *InstancePtr, 
    u8 *EdidDataPtr, 
    u16 Length);

5. For each subsystem instance, the data structures declared in steps 2 and 3 need to be initialized based on its hardware configuration, which is passed through metadata structure from xparameters.h uniquely identified by device ID.

To initialize the subsystem, call the following two API functions:

XV_HdmiRxSs_Config* XV_HdmiRxSs_LookupConfig(u32 DeviceId);
int XV_HdmiRxSs_CfgInitialize(XV_HdmiRxSs *InstancePtr, 
    XV_HdmiRxSs_Config *CfgPtr, 
    u32 EffectiveAddr);

The Device ID can be found in xparameters.h:

 XPAR_[HDMI RX Subsystem Instance Name in IPI]_DEVICE_ID

6. Each interrupt source has an associated ISR defined in the subsystem. Register the ISR with the system interrupt controller and enable the interrupt.

int XIntc_Connect(XIntc *InstancePtr, 
    u8 Id, 
    XInterruptHandler Handler, 
    void *CallBackRef);

void XIntc_Enable(XIntc *InstancePtr, 
    u8 Id);

Where ID can be found in xparameters.h.

Note:
1. Prepare the 256 bytes of EDID data and store in an array before calling the mentioned API function.
2. The EDID data is loaded into the HDMI 1.4/2.0 Receiver Subsystem during initialization. This is handled by the subsystem driver, no user intervention is needed.

**HDCP RX Overview**

The HDMI 1.4/2.0 Receiver Subsystem driver is responsible for combining HDCP 1.4 and HDCP 2.2 drivers APIs into a single common API for use by the user level application. The common HDCP driver API is able to handle the following HDCP configurations: HDCP 1.4 only, HDCP 2.2 only, and both. When both protocols are enabled, the common HDCP driver ensures that only one is active at any given time.

**HDCP RX Driver Integration**

This section describes the steps required to initialize and run the HDCP RX. The application should call the functions roughly in the order specified to ensure that the driver operates properly. When only a single HDCP protocol is enabled, either 1.4 or 2.2, a subset of the function calls might be needed.
1. Load the HDCP production keys into the HDMI subsystem. This function needs to be called for each key that is loaded. If HDCP 1.4 and 2.2 are enabled all the keys must be loaded, otherwise a subset of the keys are loaded. Note that the byte arrays used to store the key octet strings for HDCP are defined in big endian byte order.

   ○ XV_HdmiRxSS_HdcpSetKey
     - XV_HDMIRXSS_KEY_HDCP14
     - XV_HDMIRXSS_KEY_HDCP22_LC128 (128-bit DCP Licensed Constant)
     - XV_HDMIRXSS_KEY_HDCP22_PRIVATE (902-byte DCP Receiver Device Key Set)

<table>
<thead>
<tr>
<th>Position in Bytes</th>
<th>Size in Bytes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–39</td>
<td>40</td>
<td>Reserved</td>
</tr>
<tr>
<td>40–561</td>
<td>522</td>
<td>Device Public Certificate</td>
</tr>
<tr>
<td>562–901</td>
<td>340</td>
<td>Device Private Key</td>
</tr>
</tbody>
</table>

2. Initialize the HDMI 1.4/2.0 Receiver Subsystem driver after the HDCP keys have been loaded. Initializing the subsystem begins the HDCP 1.4/2.2 drivers internally.

3. Connect the HDCP interrupt handlers to the interrupt controller interrupt ID:

   ○ XV_HdmiRxSS_HdcpIntrHandler
   ○ XV_HdmiRxSS_HdcpTimerIntrHandler

4. Set the HDCP authenticated user callback. This callback is executed when the HDCP authentication state machine has reached the authenticated state. If there is no use for this function at the application level, then leave this callback undefined.

   ○ XV_HdmiRxSs_SetCallback
     - XV_HDMIRXSS_HANDLER_HDCP_AUTHENTICATE

5. Execute the poll function to run the HDCP state machine. This function checks to see which HDCP protocol is enabled, and then execute only the active protocol. The call to this function can be inserted in the main loop of the user application and should execute continuously. Because the HDCP RX state machine is run using this poll function, it is important to ensure that this function is given adequate CPU runtime, especially during authentication attempts.

   ○ XV_HdmiRxSs_HdcpPoll

6. Set the HDCP protocol to either HDCP 1.4, HDCP 2.2, or none. Setting the HDCP protocol is required to inform the HDMI subsystem which protocol is active thus avoiding collisions between protocols. Also, check which protocol has been activated.

   ○ XV_HdmiRxSs_HdcpSetProtocol
     - XV_HDMIRXSS_HDCP_NONE
     - XV_HDMIRXSS_HDCP_14
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- XV_HDMIRXSS_HDCP_22
  - XV_HdmiRxSs_HdcpGetProtocol

7. Check the status of authentication.
   - XV_HdmiRxSs_HdcpIsAuthenticated

8. Check the status of the cipher encryption. This is the instantaneous encryption status of
   the cipher and can change between subsequent frames.
   - XV_HdmiRxSs_HdcpIsEncrypted

9. Check the overall HDCP protocol status and log data. You can also set the level of detail
   for log information reported.
   - XV_HdmiRxSs_HdcpInfo
   - XV_HdmiRxSs_SetInfoDetail

**Integrate Video PHY Controller Driver for HDMI RX Subsystem Usage**

Because the HDMI 1.4/2.0 Receiver Subsystem is closely coupled with the Video PHY
Controller, the following example code demonstrates how a Video PHY Controller can be
used in your application.
To integrate and use the Video PHY Controller for HDMI 1.4/2.0 Receiver Subsystem in the application code, the following steps must be followed:

1. Include the subsystem header file `xvphy.h` that defines the subsystem object.
2. Declare and allocate space for a Video PHY Controller instance in your application code.

   Example:
   
   ```c
   XVphy Vphy;
   XVphy_Config *XVphyCfgPtr;
   ```

3. In the Video PHY Controller instance, there is a metadata structure to store its hardware configuration. Declare a pointer variable in the application code to point to the instance:

   ```c
   XVphy_Config *XVphyCfgPtr;
   ```

   ```c
   XVphy_Vphy; /* VPHY structure */
   XVphy_Config *XVphyCfgPtr;
   // Initialize Video PHY
   XVphyCfgPtr = XVphy_HdmInitialize(&Vphy, 0,
   XVphyCfgPtr, XPAR_CPU_CORE_CLOCK_FREQ_HZ);
   if (XVphyCfgPtr == NULL) {
       print("Video PHY device not found\n\r");
       return XST_FAILURE;
   }
   
   /* Initialize HDMI VPHY */
   Status = XVphy_HdmInitialize(&Vphy, 0,
   XVphyCfgPtr, XPAR_CPU_CORE_CLOCK_FREQ_HZ);
   if (Status != XST_SUCCESS) {
       print("HDMI VPHY initialization error\n\r");
       return XST_FAILURE;
   }
   
   /* Register VPHY Interrupt Handler */
   Status = XIntc_Connect(&Intc,
   XPAR_MICROBLAZE_SS_AXI_INTC_0_VID_PHY_CONTROLLER_0_IRQ_INTR,
   (InterruptHandler)XVphy_InterruptHandler,
   (void *)&Vphy);
   if (Status != XST_SUCCESS) {
       print("HDMI VPHY Interrupt Vxip ID not found!\n\r");
       return XST_FAILURE;
   }
   
   /* Enable VPHY Interrupt */
   XIntc_Enable(&Intc,
   XPAR_MICROBLAZE_SS_AXI_INTC_0_VID_PHY_CONTROLLER_0_IRQ_INTR);
   ```

   **Figure C-4**: Application Example Code
4. For each Video PHY Controller instance, the above data structure needs to be initialized based on its hardware configuration, which is passed through meta-structure from xparameters.h uniquely identified by device ID.

To initialize the Video PHY Controller, call the following two API functions:

```c
XVphy_Config *XVphy_LookupConfig(u16 DeviceId);
void XVphy_HdmInitialize(XVphy *InstancePtr,
    u8 QuadId,
    XVphy_Config *CfgPtr,
    u32 SystemFrequency);
```

The Device ID can be found in xparameters.h:

```
 XPAR_[Video PHY Controller Instance Name in IPI]_DEVICE_ID
```

Similarly, SystemFrequency is the system frequency, which can also be found in xparameters.h

**Note:**

- Xilinx recommends initializing the Video PHY controller after the HDMI 1.4/2.0 Receiver Subsystem initialization is completed.
- Registering the Video PHY Controller interrupts are part of system application integration. Steps are shown in the previous section and not repeated here.

**Interrupts**

All interrupts generated by the HDMI 1.4/2.0 Receiver Subsystem are listed here:

1. **HPD** – Peripheral I/O to detect HDMI cable 5.0V signal
   a. **Rising edge** – Cable connected
   b. **Falling edge** – Cable disconnected
2. **Link Ready** – Every time when Video PHY Controller is reconfigured, the link_clk is regenerated. An HDMI RX sub-core register bit (link status bit) reflects the change of link_clk status. When stable link_clk is detected, it is set to 1. When link_clk becomes unstable, it is set to 0. The Link Ready is an interrupt to detect the change of the link status bit.
   a. **Rising edge** – Link is up
   b. **Falling edge** – Link is down
3. **Video Ready** – This interrupt is generated by HDMI RX sub-core to reflect the status of received video stream.
   a. **Rising edge** – Video Stream is stable (StreamUp)
   b. **Falling edge** – Video Stream is not stable (StreamDown)
4. **HDMI Receiver Auxiliary Infoframe Interrupt** – This interrupt is generated when an Auxiliary Infoframe is received.

5. **HDMI Receiver Audio Infoframe Interrupt** – This interrupt is generated when an Audio Infoframe is received.

6. HDCP 1.4 Interrupt (only available when HDCP 1.4 is enabled in hardware)

7. HDCP 1.4 Timer Interrupt (only available when HDCP 1.4 is enabled in hardware)

### Table C-1: Mapping between Interrupt Sources and Application Callback Functions

<table>
<thead>
<tr>
<th>Interrupts</th>
<th>Callback</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPD</td>
<td>XV_HDMIRXSS_HANDLER_CONNECT</td>
</tr>
<tr>
<td>Link Ready</td>
<td></td>
</tr>
<tr>
<td>Video Ready</td>
<td>XV_HDMIRXSS_HANDLER_STREAM_UP</td>
</tr>
<tr>
<td><strong>Note:</strong> It is edge triggered.</td>
<td></td>
</tr>
<tr>
<td>Video Ready</td>
<td>XV_HDMIRXSS_HANDLER_STREAM_DOWN</td>
</tr>
<tr>
<td>Video Ready</td>
<td>Video Ready rising edge: Stream Up</td>
</tr>
<tr>
<td>Video Ready</td>
<td>Video Ready falling edge: Stream Down</td>
</tr>
<tr>
<td>HDMI Receiver Auxiliary Infoframe Interrupt</td>
<td>XV_HDMIRXSS_HANDLER_AUX</td>
</tr>
<tr>
<td>HDMI Receiver Audio Infoframe Interrupt</td>
<td>XV_HDMIRXSS_HANDLER_AUD</td>
</tr>
<tr>
<td>HDCP 1.4 Interrupt</td>
<td></td>
</tr>
<tr>
<td>HDCP 1.4 Timer Interrupt</td>
<td></td>
</tr>
<tr>
<td>HDCP 2.2 Timer Interrupt (only available when HDCP 2.2 is enabled in hardware)</td>
<td>XV_HDMIRXSS_HANDLER_HDCP_AUTHENTICATE</td>
</tr>
<tr>
<td><strong>Note:</strong> This callback function is not directly mapped to any interrupt source. Instead it is executed when stream is detected and Video PHY Controller is stabilized for HDMI RX Subsystem to start stream locking.</td>
<td></td>
</tr>
</tbody>
</table>

### Application Callback Functions

Subsystem driver provides a mechanism for the application to register a user-defined function that gets called within an interrupt context.

Callback functions defined in the application code must be registered with provided handlers, using the following defined API:

```c
int XV_HdmiRxSs_SetCallback(XV_HdmiRxSs *InstancePtr,
                             int InterruptId, int CallbackId);
```
Available handlers are defined in `xv_hdmirxss.h`:

- `XV_HDMIRXSS_HANDLER_CONNECT`
- `XV_HDMIRXSS_HANDLER_AUX`
- `XV_HDMIRXSS_HANDLER_AUD`
- `XV_HDMIRXSS_HANDLER_STREAM_UP`
- `XV_HDMIRXSS_HANDLER_STREAM_DOWN`
- `XV_HDMIRXSS_HANDLER_STREAM_INIT`
- `XV_HDMIRXSS_HANDLER_HDCP_AUTHENTICATE`

**XV_HDMIRXSS_HANDLER_CONNECT**

This interrupt is triggered every time when an HDMI RX cable connection or disconnection (HPD level transition) occurs.

The callback function needs to perform the following:

1. Enable or disable the differential input clock buffer depending on if cable connection or disconnection occurs, respectively.

   ```c
   void XVphy_IBufDsEnable(XVphy *InstancePtr,
                           u8 QuadId,
                           XVphy_DirectionType Dir,
                           u8 Enable);
   ```

2. Clear Video PHY RX TMDS Clock ratio when cable is disconnected:

   ```c
   Vphy.HdmiRxTmdsClockRatio = 0;
   ```

**XV_HDMIRXSS_HANDLER_AUX**

This interrupt is triggered every time when an Auxiliary InfoFrame packet is received.

The callback function needs to retrieve the InfoFrame packet data for system application to use.

**XV_HDMIRXSS_HANDLER_AUD**

This interrupt is triggered every time when an active audio stream is detected or the number of active audio channels changes.

The callback function can update the audio information to the application software.
**XV_HDMIRXSS_HANDLER_STREAM_UP**

This interrupt is triggered every time when an HDMI video stream becomes locked.

The callback function can update stream up information to the application software.

**XV_HDMIRXSS_HANDLER_STREAM_DOWN**

This interrupt is triggered when an HDMI video stream turns unlocked.

The callback function can update stream down information to the application software. The application software might start a timer and put the system into standby mode if the HDMI 1.4/2.0 Receiver Subsystem remains unlocked for a certain time.

**XV_HDMIRXSS_HANDLER_STREAM_INIT**

This interrupt is triggered every time a stream is detected and the Video PHY Controller is stabilized for the HDMI 1.4/2.0 Receiver Subsystem to start stream locking.

The callback function needs to perform the following steps:

1. Check the event is for cable connected or cable disconnected.

   ```c
   XV_HdmiRxSs *HdmiRxSsPtr = (XV_HdmiRxSs *)CallbackRef;
   HdmiRxSsPtr->IsStreamConnected
   1 - Connected
   0 - Disconnected
   ```

2. Retrieve the video stream information.

   ```c
   XVidC_VideoStream *XV_HdmiRxSs_GetVideoStream(
      XV_HdmiRxSs *InstancePtr);
   ```

3. Calculate HDMI MMCM parameter based on the video stream information received.

   ```c
   u32 XVphy_HdmiCfgCalcMmcmParam(XVphy *InstancePtr,
   u8 QuadId,
   XVphy_ChannelId ChId,
   XVphy_DirectionType Dir,
   XVidC_PixelsPerClock Ppc,
   XVidC_ColorDepth Bpc);
   ```

4. Enable the Video PHY Controller to start MMCM.

   ```c
   XVphy_MmcStart(&Vphy, 0, XVPHY_DIR_RX);
   ```

**XV_HDMIRXSS_HANDLER_HDCP_AUTHENTICATE**

If HDCP 1.4 or HDCP 2.2 is enabled in the HDMI 1.4/2.0 Receiver Subsystem hardware, this interrupt is triggered when HDCP passes its authentication state.

The callback function can update HDCP authentication status to the application software.
**Video PHY Controller Interrupt Handlers for HDMI 1.4/2.0 Receiver Subsystem**

There are several interrupt handlers available in the Video PHY Controller driver to hook up with user-defined callback functions to support HDMI 1.4/2.0 Receiver Subsystem functionality. These interrupt handlers are defined in `xvphy.h`:

- XVPHY_HDMI_HANDLER_RXINIT
- XVPHY_HDMI_HANDLER_RXREADY

Callback functions need to be defined in the application code and hooked up with these interrupt handlers.

```c
void XVphy_SetHdmiCallback(XVphy *InstancePtr,
                           XVphy_HdmiHandlerType HandlerType,
                           void *CallbackFunc,
                           void *CallbackRef);
```

**XVPHY_HDMI_HANDLER_RXINIT**

This interrupt is triggered every time the Video PHY Controller detects an HDMI RX reference clock changes.

The callback function needs to perform the following:

1. Initialize a reference clock change process for an HDMI 1.4/2.0 Receiver Subsystem.
   ```c
   void XV_HdmiRxSs_RefClockChangeInit(XV_HdmiRxSs *InstancePtr);
   ```

2. Set Video PHY Controller HDMI RX reference TMDS clock ratio.
   ```c
   VphyPtr->HdmiRxTmdsClockRatio = HdmiRxSs.TMDSClockRatio;
   ```

**XVPHY_HDMI_HANDLER_RXREADY**

This interrupt is triggered every time the Video PHY Controller RX reset lock is done.

The callback function needs to perform the following:

1. Check the Video PHY Controller PLL Type.
   ```c
   XVphy_Pl1Type XVphy_GetPl1Type(XVphy *InstancePtr,
                                   u8 QuadId,
                                   XVphy_DirectionType Dir,
                                   XVphy_ChannelId ChId);
   ```

2. Set the HDMI 1.4/2.0 Receiver Subsystem Video Stream according to the PLL type.
   ```c
   XV_HdmiRxSs_SetStream(XV_HdmiRxSs *InstancePtr,
                          u32 Clock,
                          u32 LineRate);
   ```

   Where both Clock and LineRate are from Video PHY Controller data structure.
Follow the steps in Chapter 5, Example Design to create an example design, which contains all the procedures implemented and can serve as a reference for integrating the HDMI 1.4/2.0 Receiver Subsystem into your system.

**Example Use Cases**

In this section, some typical use cases are illustrated with how system reacts at run time to certain events and what is expected for you to perform. For actions expected in the callback functions, see Application Callback Functions for more information.

**Use Case 1: Cable Plug In**

HPD interrupt is received indicating Cable Connection.

• Callback function registered to `XV_HDMIRXSS_HANDLER_CONNECT` Interrupt type is called.

**Use Case 2: Cable Plug Out**

1. RX Stream Down interrupt is received.
   • Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_DOWN` interrupt type is called.
2. HPD interrupt is received indicating Cable Disconnection.
   • Callback function registered to `XV_HDMIRXSS_HANDLER_CONNECT` Interrupt type is called.

**Use Case 3: Received Video Stream**

1. Video PHY Controller HDMI RX Init interrupt is received.
   • Callback function registered to `XVPHY_HDMI_HANDLER_RXINIT` Interrupt type is called.
2. Video PHY Controller HDMI RX Ready interrupt is received.
   • Callback function registered to `XVPHY_HDMI_HANDLER_RXREADY` Interrupt type is called.
3. RX Audio Interrupt is received.
   • Callback function registered to `XV_HDMIRXSS_HANDLER_AUD` Interrupt type is called.
4. RX Stream Initialization Interrupt is received.
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- Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_INIT` Interrupt type is called.

5. When Video stream is locked, the RX stream up interrupt is received.
- Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_UP` Interrupt type is called.

Now, the video stream has been detected and you can retrieve the stream information using the provided API:

```c
XVidC_VideoStream *XV_HdmiRxSs_GetVideoStream(
    XV_HdmiRxSs *InstancePtr);
```

Use Case 4: Video Stream Change

1. RX Stream Down interrupt is received.
   - Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_DOWN` interrupt type is called.

2. Video PHY Controller HDMI RX Init interrupt is received.
   - Callback function registered to `XVPHY_HDMI_HANDLER_RXINIT` Interrupt type is called.

3. Video PHY Controller HDMI RX Ready interrupt is received.
   - Callback function registered to `XVPHY_HDMI_HANDLER_RXREADY` Interrupt type is called.

4. RX Audio Interrupt is received.
   - Callback function registered to `XV_HDMIRXSS_HANDLER_AUD` Interrupt type is called.

5. RX Stream Initialization Interrupt is received.
   - Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_INIT` Interrupt type is called.

6. When Video stream is locked, the RX stream up interrupt is received.
   - Callback function registered to `XV_HDMIRXSS_HANDLER_STREAM_UP` Interrupt type is called.

Now, the video stream has been detected and you can retrieve the stream information using the provided API:

```c
XVidC_VideoStream *XV_HdmiRxSs_GetVideoStream(
    XV_HdmiRxSs *InstancePtr);
```

Use Case 5: Receive Infoframe

The Auxiliary InfoFrame received interrupt is received.
Callback function registered to `XV_HDMIRXSS_HANDLER_AUX` Interrupt type is called.

**Use Case 6: How to Disable Internal EDID**

If you do not want to enable the internal EDID support, you can comment out the function `XV_HdmiRx_DdcLoadEdid` in `xv_hdmirxss_coreinit.c`, under function call.

```c
int XV_HdmiRxSs_SubcoreInitHdmiRx(XV_HdmiRxSs *HdmiRxSsPtr)

Example:

// Load EDID
// XV_HdmiRx_DdcLoadEdid(HdmiRxSsPtr->HdmiRxPtr, HdmiRxSsPtr->EdidPtr,
//     HdmiRxSsPtr->EdidLength);
```
Appendix D

Additional Resources and Legal Notices

Xilinx Resources

For support resources such as Answers, Documentation, Downloads, and Forums, see Xilinx Support.

References

These documents provide supplemental material useful with this product guide:

1. Xilinx Vivado AXI Reference Guide (UG1037)
2. Kintex UltraScale FPGAs Data Sheet: DC and AC Switching Characteristics (DS892)
3. Virtex UltraScale FPGAs Data Sheet: DC and AC Switching Characteristics (DS893)
4. Kintex-7 FPGAs Data Sheet: DC and AC Switching Characteristics (DS182)
5. Virtex-7 FPGAs Data Sheet: DC and AC Switching Characteristics (DS183)
6. Artix-7 FPGAs Data Sheet: DC and AC Switching Characteristics (DS181)
7. Kintex UltraScale+ FPGAs Data Sheet: DC and AC Switching Characteristics (DS922)
8. Virtex UltraScale+ FPGAs Data Sheet: DC and AC Switching Characteristics (DS923)
9. Zynq UltraScale+ MPSoC Data Sheet: DC and AC Switching Characteristics (DS925)
10. HDMI specifications (www.hDMI.org/manufacturer/specification.aspx)
11. HDCP specifications (www.digital-cp.com/hdcp Specifications)
12. AXI4-Stream Video IP and System Design Guide (UG934)
17. ISE to Vivado Design Suite Migration Guide (UG911)
18. KCU105 Board User Guide (UG917)
21. AXI Interconnect LogiCORE IP Product Guide (PG059)
23. HDCP v2.2 Product Guide (PG249)
24. HDCP v1.4 Product Guide (PG224)
25. Video In to AXI4-Stream LogiCORE IP Product Guide (PG043)

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**Revision History**

The following table shows the revision history for this document.

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<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Revision</th>
</tr>
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<tbody>
<tr>
<td>04/05/2017</td>
<td>2.0</td>
<td>• Removed single pixel per clock support</td>
</tr>
<tr>
<td>11/30/2016</td>
<td>2.0</td>
<td>• Added example design migration notes.</td>
</tr>
<tr>
<td>10/05/2016</td>
<td>2.0</td>
<td>• Added example design flow.</td>
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<td>• Added HPD XGUI option.</td>
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<td>• Added software use cases.</td>
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<td>Updated Xilinx ACTIVOMATIC APPLICATIONS DISCLAIMER.</td>
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<tr>
<td>06/08/2016</td>
<td>2.0</td>
<td>• Updated optional video over AXI-Stream support.</td>
</tr>
<tr>
<td>04/06/2016</td>
<td>2.0</td>
<td>• Added Features section in IP Facts.</td>
</tr>
<tr>
<td></td>
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<td>• Updated Unsupported Features in Overview chapter.</td>
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<td>• Updated Product Specification chapter.</td>
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<td>• Updated Designing with the Subsystem chapter.</td>
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<td>• Updated Design Flow Steps chapter.</td>
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<td></td>
<td></td>
<td>• Updated Hardware Testing and Video Resolutions sections.</td>
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<td>• Updated Application Software Development appendix.</td>
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<tr>
<td>11/18/2015</td>
<td>1.0</td>
<td>Initial Xilinx release.</td>
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