

# Gamma LUT v1.0

## *LogiCORE IP Product Guide*

PG285 December 5, 2018



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## Introduction

The Xilinx LogiCORE™ IP Gamma LUT core provides customers with an optimized hardware block for manipulating image data to match the response of display devices. This core is implemented using a look-up table structure that is programmed to implement a gamma correction curve transform on the input image data.

## Features

- Programmable gamma table supports gamma correction or any user defined function
- Three channel independent look-up table structure
- One, two, four or eight pixel-wide AXI4-Stream video interface
- 8 and 10 bits per component support
- Supports spatial resolutions from 64 x 64 up to 8192 x 4320
- Supports 4K60 in all supported device families<sup>(1)</sup>

1. Performance on low power devices might be lower.

| LogiCORE IP Facts Table   |  |
|---|--|
| <b>Core Specifics</b>   |  |
| Supported Device Family <sup>(1)</sup>                            | UltraScale+™ Families, UltraScale™ Architecture, Zynq® -7000, 7 Series                       |
| Supported User Interfaces   | AXI4-Lite, AXI4-Stream <sup>(2)</sup>  |
| Resources   | <a href="#">Performance and Resource Utilization web page</a>                                |
| <b>Provided with Core</b>   |  |
| Documentation   | Product Guide  |
| Design Files  | Not Provided   |
| Example Design  | Yes  |
| Test Bench  | Not Provided   |
| Constraints File  | XDC  |
| Simulation Models   | Encrypted RTL, VHDL or Verilog Structural  |
| Supported Software Drivers <sup>(3)</sup>                         | Standalone, V4L2   |
| <b>Tested Design Flows<sup>(4)</sup></b>                          |  |
| Design Entry Tools  | Vivado® Design Suite   |
| Simulation  | For supported simulators, see the <a href="#">Xilinx Design Tools: Release Notes Guide</a> . |
| Synthesis Tools   | Vivado Synthesis   |
| <b>Support</b>  |  |
| Provided by Xilinx at the <a href="#">Xilinx Support web page</a> |  |

1. For a complete listing of supported devices, see the Vivado IP Catalog.
2. Video protocol as defined in the *Video IP: AXI Feature Adoption* section of *AXI Reference Guide* [Ref 1].
3. Standalone driver details can be found in the SDK directory (<install\_directory>/SDK/<release>/data/embeddedsw/doc/xilinx\_drivers.htm). Linux OS and driver support information is available from the [Xilinx Wiki page](#).
4. For the supported versions of the tools, see the [Xilinx Design Tools: Release Notes Guide](#).

# Overview

Gamma correction, also known as gamma compression or encoding, is used to encode linear luminance or RGB values to match the non-linear characteristics of display devices. Gamma correction helps to map data into a more perceptually uniform domain, so as to optimize perceptual performance of a limited signal range, such as a limited number of bits in each RGB component.

Gamma correction is, in the simplest cases, defined by

$$V_{out} = V_{in}^{\gamma}$$

where the input and output values are between 0 and 1 (Figure 1-1). The case  $\gamma < 1$  is often called gamma compression and  $\gamma > 1$  is called gamma expansion.

When used in conjunction with an embedded or external processor, the Gamma LUT core supports frame-by-frame dynamic reprogramming of the gamma tables. The gamma tables can be reprogrammed with arbitrary functions, supporting a wide range of applications, such as intensity correction, feature enhancement, lin-log, log-lin conversion, and thresholding.

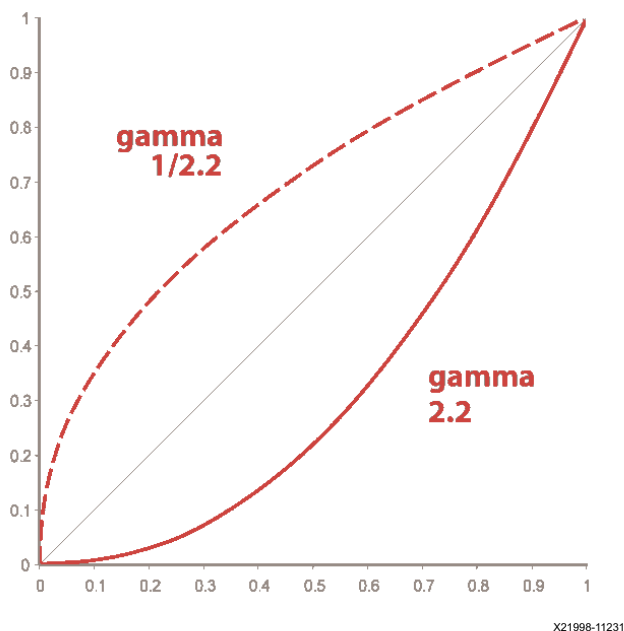


Figure 1-1: Gamma Correction

The Gamma LUT core is implemented as a set of LUTs that are used to perform the data transformation. The width of the data determines the number of entries in the LUT. For example, 8-bit data would require  $2^8$  (256) entries in the LUT. The width of the data also determines the width of each entry in the LUT. For example, 10-bit data would require that each entry in the table be 10-bits wide.

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## Feature Summary

The Gamma LUT core provides programmable look-up tables for gamma correction.

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## Applications

- Pre-processing block for image sensors
- Post-processing block for image data adjustment
- Intensity correction
- Video surveillance
- Consumer displays
- Video conferencing
- Machine vision

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## Licensing and Ordering

This Xilinx® LogiCORE™ IP module is provided at no cost 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 core functionalities in simulation and in hardware, you must request a free license for the core. Contact your [local Xilinx sales representative](#) for information about pricing and availability.

For more information, visit the [Gamma LUT product 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](#).

# Product Specification

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## Standards

The Gamma LUT core is compliant with the AXI4-Stream Video Protocol and AXI4-Lite interconnect standards. Refer to the *Video IP: AXI Feature Adoption* section of the *Vivado AXI Reference Guide* (UG1037) [Ref 1] and *AXI4-Stream Video IP and System Design Guide* (UG934) [Ref 2] for additional information.

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## Performance

The following sections detail the performance characteristics of the Gamma LUT core.

### Maximum Frequencies

The following are typical clock frequencies for the target devices:

- UltraScale™+ devices with -1 speed grade or higher: 300 MHz
- Virtex<sup>®</sup>-7 and Virtex UltraScale™ devices with -2 speed grade or higher: 300 MHz
- Kintex<sup>®</sup>-7 and Kintex UltraScale™ devices with -2 speed grade or higher: 300 MHz
- Artix<sup>®</sup>-7 devices with -2 speed grade or higher: 150 MHz

The maximum achievable clock frequency can vary. The maximum achievable clock frequency and all resource counts can be affected by other tool options, additional logic in the device, using a different version of Xilinx<sup>®</sup> tools, and other factors.

### Throughput

The Gamma LUT supports bi-directional data throttling between its AXI4-Stream slave and master interfaces. If the slave side data source is not providing valid data samples (`s_axis_video_tvalid` is not asserted), the core cannot produce valid output samples after its internal buffers are depleted. Similarly, if the master side interface is not ready to accept valid data samples (`m_axis_video_tready` is not asserted) the core cannot accept valid input samples after its buffers become full.



If the master interface is able to provide valid samples (`s_axis_video_tvalid` is High) and the slave interface is ready to accept valid samples (`m_axis_video_tready` is High), typically the core can process and produce one, two, or four pixels specified by **Samples Per Clock** in the Vivado Integrated Design Environment (IDE) per `ap_clk` cycle.

However, at the end of each scan line and frame the core flushes internal pipelines for several clock cycles, during which the `s_axis_video_tready` is deasserted signaling that the core is not ready to process samples.

When the Gamma LUT is processing timed streaming video (which is typical for most video sources), the flushing periods coincide with the blanking periods and therefore do not reduce the throughput of the system.

When operating on a streaming video source (that is, not frame buffered data), the Gamma LUT must operate minimally at the burst data rate. For example, 148.5 MHz for a 1080p60 video source for a one sample per clock configuration of the IP. For a 4K 60 fps video source, the core must operate at 297 MHz for a two sample per clock configuration, or 148.5 MHz for a four sample per clock configuration on slower devices such as Artix®-7.

## Resource Utilization

For full details about performance and resource utilization, visit the [Video Gamma LUT Performance and Resource Utilization web page](#).

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## Register Space

### Port Descriptions

The Gamma LUT core uses industry standard control and data interfaces to connect to other system components. The following sections describe the various interfaces available with the core. [Figure 2-1](#) illustrates an I/O diagram of the Gamma LUT core.

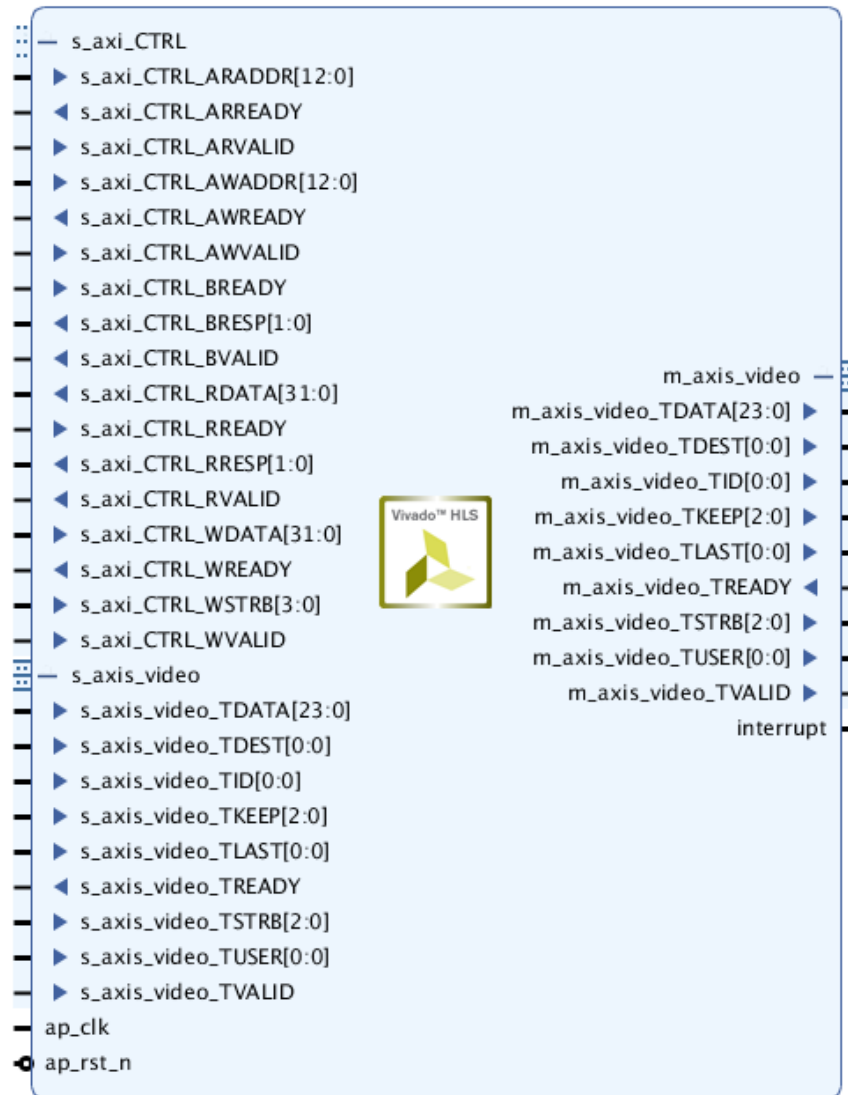


Figure 2-1: Gamma LUT Core Top-Level Signaling Interface

## Common Interface Signals

Table 2-1 summarizes the signals which are either shared by, or not part of the dedicated AXI4-Stream data or AXI4-Lite control interfaces.

Table 2-1: Common Interface Signals

| Signal Name | Direction | Width | Description                        |
|-------------|-----------|-------|------------------------------------|
| AP_CLK      | I         | 1     | Video Core Clock                   |
| AP_RST_N    | I         | 1     | Video Core Active Low Clock Enable |
| INTERRUPT   | OO        | 1     | Interrupt Request Pin              |

The AP\_CLK and AP\_RST\_N signals are shared between the core, the AXI4-Stream data interfaces, and the AXI4-Lite control interface. The INTERRUPT pin is not supported and reserved for future use.

### AP\_CLK

The AXI4-Stream and AXI4-Lite interfaces must be synchronous to the core clock signal AP\_CLK. All AXI4-Stream interface input signals and AXI4-Lite control interface input signals are sampled on the rising edge of AP\_CLK. All AXI4-Stream output signal changes occur after the rising edge of AP\_CLK.

### AP\_RST\_N

The AP\_RST\_N pin is an active-Low, synchronous reset input pertaining to both AXI4-Lite and AXI4-Stream interfaces. When AP\_RST\_N is set to 0, the core resets at the next rising edge of AP\_CLK.

## Data Interface

The Gamma LUT core receives and transmits data using AXI4-Stream interfaces that implement a video protocol as defined in the *Video IP: AXI Feature Adoption* section of the (UG761) *AXI Reference Guide* [Ref 3].

### AXI4-Stream Signal Names and Descriptions

Table 2-2 describes the AXI4-Stream signal names and descriptions.



**IMPORTANT:** In Table 2-2,  $TotalDataWidth = 3 * data\_width * samples\_per\_clock$ . The values correspond to Maximum Data Width and Samples Per Clock in the IDE, respectively. Refer to Chapter 4, *Design Flow Steps* for more information.

Table 2-2: AXI4-Stream Data Interface Signal Descriptions

| Signal Name         | Direction | Width                          | Description  |
|---------------------|-----------|--------------------------------|--|
| s_axis_video_tdata  | I         | $(TotalDataWidth + 7) / 8 * 8$ | Input Video Data   |
| s_axis_video_tvalid | I         | 1                              | Input Video Valid Signal   |
| s_axis_video_tready | O         | 1                              | Input Ready  |
| s_axis_video_tuser  | I         | 1                              | Input Video Start Of Frame   |
| s_axis_video_tlast  | I         | 1                              | Input Video End Of Line  |
| s_axi_video_tstrb   | I         | s_axis_video tdata/8           | Input video data strobe indicates whether the content of the associated byte of TDATA is processed as a data byte or a position byte |

Table 2-2: AXI4-Stream Data Interface Signal Descriptions (Cont'd)

| Signal Name         | Direction | Width                  | Description  |
|---------------------|-----------|------------------------|--|
| s_axi_video_tkeep   | I         | s_axis_video_tdata/8   | Input video byte qualifier that indicates whether the content of the associated byte of TDATA is processed as part of the data stream  |
| s_axi_video_tid     | I         | 1                      | Input video data stream identifier   |
| s_axi_video_tdest   | I         | 1                      | Input video data routing information   |
| m_axis_video_tdata  | O         | (TotalDataWidth+7)/8*8 | Output Video Data  |
| m_axis_video_tvalid | O         | 1                      | Output Valid   |
| m_axis_video_tready | I         | 1                      | Output Ready   |
| m_axis_video_tuser  | O         | 1                      | Output Video Start Of Frame  |
| m_axis_video_tlast  | O         | 1                      | Output Video End Of Line   |
| m_axi_video_tstrb   | O         | m_axis_video_tdata/8   | Output video data strobe indicates whether the content of the associated byte of TDATA is processed as a data byte or a position byte  |
| m_axi_video_tkeep   | O         | m_axis_video_tdata/8   | Output video byte qualifier that indicates whether the content of the associated byte of TDATA is processed as part of the data stream |
| m_axi_video_tid     | O         | 1                      | Output video data stream identifier  |
| m_axi_video_tdest   | O         | 1                      | Output video data routing information  |

## Video Data

The AXI4-Stream interface specification restricts TDATA widths to integer multiples of 8 bits. Therefore, any bit data must be padded with zeros on the MSB to form a N\*8 bit wide vector before connecting to s\_axis\_video\_tdata. Padding does not affect the size of the core.

Similarly, data on the Gamma LUT output m\_axis\_video\_tdata is packed and padded to multiples of 8 bits as necessary. Zero padding the most significant bits is only necessary for 10-bit wide data. [Figure 2-2](#) and [Figure 2-3](#) explain the pixel mapping of AXI4-Stream interface with 2 pixels per clock and 10 bits per component configuration for all supporting color formats. Zero padding (bits [63:60]) is not shown in the figures.

|       |       |       |       |       |     |
|-------|-------|-------|-------|-------|-----|
| 59:50 | 49:40 | 39:30 | 29:20 | 19:10 | 9:0 |
| R1    | B1    | G1    | R0    | B0    | G0  |

X21993-112318

Figure 2-2: Dual Pixels per Clock, 10 bits per Component Mapping for RGB

|       |       |       |       |       |     |
|-------|-------|-------|-------|-------|-----|
| 59:50 | 49:40 | 39:30 | 29:20 | 19:10 | 9:0 |
| V1    | U1    | Y1    | V0    | U0    | Y0  |

X21992-112318

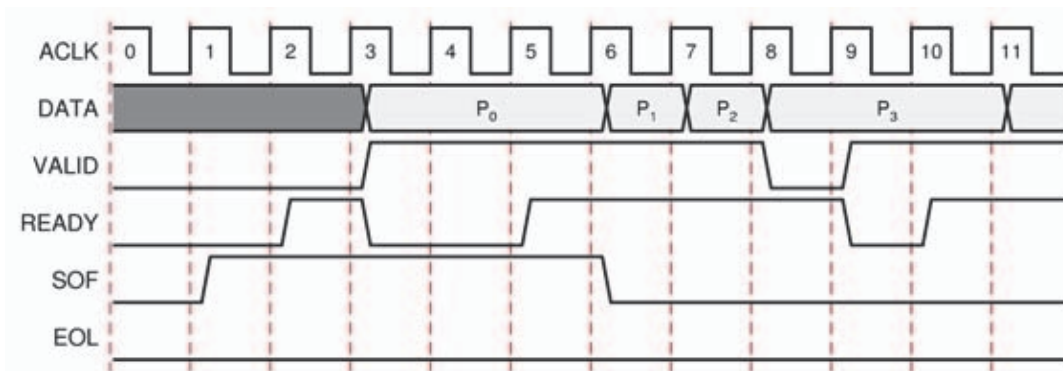
Figure 2-3: Dual Pixels per Clock, 10 bits per Component Mapping for YUV 4:4:4

### READY/VALID Handshake

A valid transfer occurs whenever READY, VALID, and AP\_RST\_N are High at the rising edge of AP\_CLK, as seen in Figure 2-4. During valid transfers, DATA only carries active video data. Blank periods and ancillary data packets are not transferred through the AXI4-Stream video protocol.

### Guidelines on Driving s\_axis\_video\_tvalid

When s\_axis\_video\_tvalid is asserted, no interface signals (except the Gamma LUT core driving s\_axis\_video\_tready) can change value until the transaction completes. The s\_axis\_video\_tready, s\_axis\_video\_tvalid, and AP\_RST\_N signals are High on the rising edge of AP\_CLK. When asserted, s\_axis\_video\_tvalid can only be deasserted after a transaction has completed. Transactions cannot be retracted or aborted. In any cycle following a transaction, s\_axis\_video\_tvalid can either be deasserted or remain asserted to initiate a new transfer.



X21996-112318

Figure 2-4: Example of READY/VALID Handshake, Start of a New Frame

### Guidelines on Driving `m_axis_video_tready`

The `m_axis_video_tready` signal can be asserted before, during, or after the cycle in which the Gamma LUT core asserts `m_axis_video_tvalid`. The assertion of the `m_axis_video_tready` signal can be dependent on the value of the `m_axis_video_tvalid` signal. A slave that can immediately accept data qualified by `m_axis_video_tvalid` should preassert its `m_axis_video_tready` signal until data is received. Alternatively, `m_axis_video_tready` can be registered and driven the cycle following `VALID` assertion.



**RECOMMENDED:** To minimize latency, your custom core slave interface should drive `READY` independently, or preassert `READY`.

### Start of Frame Signals - `m_axis_video_tuser0`, `s_axis_video_tuser0`

The Start-Of-Frame (SOF) signal, physically transmitted over the AXI4-Stream `TUSER0` signal, marks the first pixel of a video frame. The SOF pulse is 1 valid transaction wide, and must coincide with the first pixel of the frame, as seen in Figure 2-4. The SOF signal serves as a frame synchronization signal, which allows downstream cores to reinitialize and detect the first pixel of a frame. The SOF signal can be asserted on an arbitrary number of `AP_CLK` cycles before the first pixel value is presented on `DATA`, as long as a `VALID` is not asserted.

### End of Line Signals - `m_axis_video_tlast`, `s_axis_video_tlast`

The End-Of-Line (EOL) signal, physically transmitted over the AXI4-Stream `TLAST` signal, marks the last pixel of a line. The EOL pulse is one valid transaction wide, and must coincide with the last pixel of a scanline, as seen in Figure 2-5.

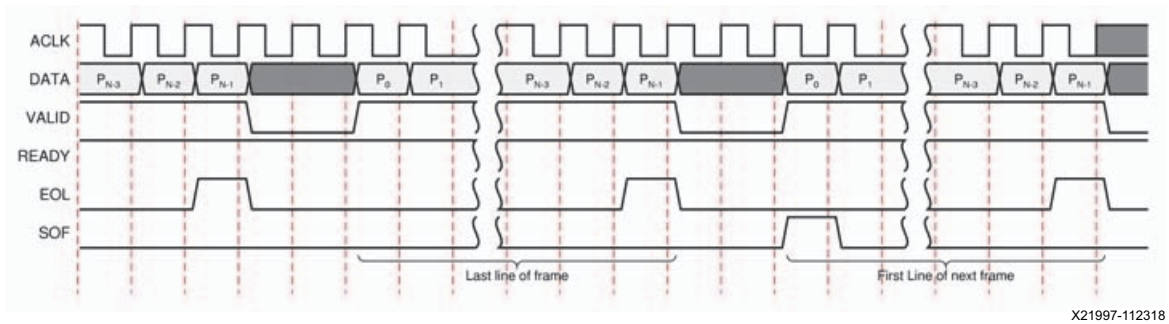


Figure 2-5: Use of EOL and SOF Signals

## Control Interface

The AXI4-Lite register interface dynamically controls the behavior of the core. The AXI4-Lite slave interface facilitates integrating the core into a processor system, or along with other video or AXI4-Lite compliant IP, connected through AXI4-Lite interface to an AXI4-Lite master. The core cannot be instantiated without the AXI4-Lite control interface.

## AXI4-Lite Interface

The AXI4-Lite interface allows you to dynamically control parameters within the core. Core configuration can be accomplished using an AXI4-Lite master state machine, or an embedded Arm or soft system processor such as a MicroBlaze™ processor.

The Gamma LUT core can be controlled through the AXI4-Lite interface by using functions provided by the driver in the SDK. Another method is performing read and write transactions to the Gamma LUT register space; this method should only be used when the first method is not available.

Table 2-3: AXI4-Lite Interface Signals

| Signal Name        | Direction | Width | Description   |
|--------------------|-----------|-------|---|
| s_axi_CTRL_awvalid | I         | 1     | AXI4-Lite Write Address Channel Write Address Valid.  |
| s_axi_CTRL_awread  | O         | 1     | AXI4-Lite Write Address Channel Write Address Ready. Indicates DMA ready to accept the write address. |
| s_axi_CTRL_awaddr  | I         | 32    | AXI4-Lite Write Address Bus   |
| s_axi_CTRL_wvalid  | I         | 1     | AXI4-Lite Write Data Channel Write Data Valid.  |
| s_axi_CTRL_wready  | O         | 1     | AXI4-Lite Write Data Channel Write Data Ready. Indicates DMA is ready to accept the write data.       |
| s_axi_CTRL_wdata   | I         | 32    | AXI4-Lite Write Data Bus  |
| s_axi_CTRL_bresp   | O         | 2     | AXI4-Lite Write Response Channel. Indicates results of the write transfer.                            |
| s_axi_CTRL_bvalid  | O         | 1     | AXI4-Lite Write Response Channel Response Valid. Indicates response is valid.                         |
| s_axi_CTRL_bready  | I         | 1     | AXI4-Lite Write Response Channel Ready. Indicates target is ready to receive response.                |
| s_axi_CTRL_arvalid | I         | 1     | AXI4-Lite Read Address Channel Read Address Valid   |
| s_axi_CTRL_arready | O         | 1     | Ready. Indicates DMA is ready to accept the read address.   |
| s_axi_CTRL_araddr  | I         | 32    | AXI4-Lite Read Address Bus  |
| s_axi_CTRL_rvalid  | O         | 1     | AXI4-Lite Read Data Channel Read Data Valid   |
| s_axi_CTRL_rready  | I         | 1     | AXI4-Lite Read Data Channel Read Data Ready. Indicates target is ready to accept the read data.       |
| s_axi_CTRL_rdata   | O         | 32    | AXI4-Lite Read Data Bus   |
| s_axi_CTRL_rresp   | O         | 2     | AXI4-Lite Read Response Channel Response. Indicates results of the read transfer.                     |

## Register Space

The core has seven core-specific registers which allow you to dynamically control the operation of the core. All registers have an initial value of 0. [Table 2-4](#) describes the register names.

**Table 2-4: Register Names and Descriptions**

| Address (hex) BASEADDR + | Register Name                | Access Type | Register Description   |
|--------------------------|------------------------------|-------------|--|
| 0x0000                   | Control                      | R/W         | Bit 0: ap_start (Read/Write/COH) <sup>(1)</sup><br>Bit 1: ap_done (Read/COR) <sup>(1)</sup><br>Bit 2: ap_idle (Read)<br>Bit 3: ap_ready (Read)<br>Bit 7: auto_restart (Read/Write)<br>Others: reserved |
| 0x0004                   | Global Interrupt Enable      | R/W         | Bit 0: Global Interrupt Enable<br>Others: reserved<br>This register is not used but reserved for future use.   |
| 0x0008                   | IP Interrupt Enable Register | R/W         | Bit 0: Channel 0 (ap_done)<br>Bit 1: Channel 1 (ap_ready)<br>Others: reserved<br>This register is not used but reserved for future use.  |
| 0x000C                   | IP Interrupt Status Register | R           | Bit 0: Channel 0 (ap_done)<br>Bit 1: Channel 1 (ap_ready)<br>Others: reserved<br>This register is not used but reserved for future use.  |
| 0x0010                   | Active Width                 | R/W         | Number of Active Pixels per Scanline   |
| 0x0018                   | Active Height                | R/W         | Number of Active Lines per Frame   |
| 0x0020                   | Video Format                 | R/W         | Specify video color format   |
| 0x0800                   | Gamma look-up table 0 (RED)  | R/W         | Word n: bit [15:0] Gamma LUT 0 [2n]<br>bit [31:16] Gamma LUT 0 [2n+1]  |



Table 2-4: Register Names and Descriptions (Cont'd)

| Address (hex) BASEADDR + | Register Name                 | Access Type | Register Description  |
|--------------------------|-------------------------------|-------------|---|
| 0x1000                   | Gamma look-up table 1 (GREEN) | R/W         | Word n: bit [15:0] Gamma LUT 1 [2n]<br>bit [31:16] Gamma LUT 1 [2n+1] |
| 0x1800                   | Gamma look-up table 2 (BLUE)  | R/W         | Word n: bit [15:0] Gamma LUT 2 [2n]<br>bit [31:16] Gamma LUT 2 [2n+1] |

**Notes:**

1. COR = Clear on Read, COH - Clear on Handshake

### **CONTROL (0x0000) Register**

This register controls the running of Gamma LUT. Bit 0 of the `control` register, `ap_start`, kicks off the core from software. Writing 1 to this bit starts the core to generate a video frame. To set the core in free running mode, bit 7 of this register, `auto_restart`, must be set to 1. Bit 1-3 are not used currently but are reserved for future use.

### **ACTIVE\_WIDTH (0x0010) Register**

The `active_width` register encodes the number of active pixels per scan. Supported values are 64 and the value provided in the **Maximum number of Columns** field in the Vivado® IDE. To avoid processing errors, restrict values written to `active_width` to the range supported by the core instance.

### **ACTIVE\_HEIGHT (0x0018) Register**

The `active_height` register encodes the number of active scan lines per frame. Supported values are between 64 and the value provided in the **Maximum number of Rows** field in the IDE. To avoid processing errors, restrict values written to `active_height` to the range supported by the core instance.

### **VIDEO\_FORMAT (0x0020) Register**

This register specifies the video format of the AXI4-Stream Video data.

- 0x0 RGB video format
- 0x1 YUV 4:4:4 video format

# Designing with the Core

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## General Design Guidelines

The Gamma LUT core uses look-up tables programmed with a gamma correction curve or user-defined function to convert input data to output data. The core processes samples provided using an AXI4-Stream slave interface, outputs pixels using an AXI4-Stream master interface, and can be controlled using the AXI4-Lite interface. The Gamma LUT block cannot change the input/output image sizes, the input and output pixel clock rates, or the frame rate. It is recommended that the Gamma LUT core is used in conjunction with the Xilinx LogiCORE IP Video In to AXI4-Stream and Video Timing Controller cores. The Video Timing Controller core measures the timing parameters, such as the number of active scan lines, and the number of active pixels per scan line of the image sensor. The Video In to AXI4-Stream core converts a clocked parallel video interface with sync and/or blank signals to an AXI4-Stream interface.

The core is implemented as a set of LUTs that are used to perform the data transformation. The width of the data determines the number of entries in the LUT. For example, 8-bit data would require  $2^8$  (256) entries in the LUT.

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## Clock, Enable, and Reset Considerations

### Clocking

The Gamma LUT IP has a single clock domain. All interfaces (master and slave AXI4-Stream video interfaces and the AXI4-Lite interface) use the `ap_clk` pin as their clock source.

### Resets

The Gamma LUT IP has only a hardware reset option, `ap_rst_n` pin. No software reset option is available. The external reset pulse must be held for 16 or more `ap_clk` cycles to reset the core. The `ap_rst_n` signal is synchronous to the `ap_clk` clock domain. The `ap_rst_n` signal resets the entire core including the AXI4-Lite and AXI4-Stream interfaces.

## System Considerations

To operate properly, the Gamma LUT IP must be configured for the actual input and output image frame size. To gather the frame size information from the image video stream, the IP can be connected to the Video In to AXI4-Stream input and the Video Timing Controller core. The timing detector logic in the Video Timing Controller gathers the video timing signals. The AXI4-Lite control interface on the Video Timing Controller allows the system processor to read out the measured frame dimensions and program all downstream cores, such as the Gamma LUT, with the appropriate image dimensions.

## Programming Sequence

All Gamma LUT processing parameters other than image size can be changed dynamically on a frame-by-frame basis, and the change is picked up immediately. If the image size must be changed, or the entire system restarts, it is recommended that pipelined Xilinx® IP video cores are disabled/reset from system output towards the system input, and programmed/enabled from system output to system input.

# Design Flow Steps

This chapter describes customizing and generating the core, constraining the core, and the simulation, synthesis and implementation steps that are specific to this IP core. More detailed information about the standard Vivado<sup>®</sup> 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) [\[Ref 9\]](#)
- *Vivado Design Suite User Guide: Designing with IP* (UG896) [\[Ref 5\]](#)
- *Vivado Design Suite User Guide: Getting Started* (UG910) [\[Ref 7\]](#)
- *Vivado Design Suite User Guide: Logic Simulation* (UG900) [\[Ref 8\]](#)

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## Customizing and Generating the Core

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

If you are customizing and generating the core in the Vivado IP integrator, see the *Vivado Design Suite User Guide: Designing IP Subsystems using IP Integrator* (UG994) [\[Ref 9\]](#) for detailed information. 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 IP for use in your design by specifying values for the various parameters associated with the IP core using the following steps:

1. Select the IP from the Vivado IP catalog.
2. Double-click the selected IP or select the **Customize IP** command from the toolbar or right-click menu.

For details, see the *Vivado Design Suite User Guide: Designing with IP* (UG896) [\[Ref 5\]](#) and the *Vivado Design Suite User Guide: Getting Started* (UG910) [\[Ref 7\]](#).

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

## Interface

This section provides a quick reference to parameters that can be configured using the Vivado Design Suite at generation time.

The Gamma LUT core is easily configured to meet your specific requirements through the Vivado Design Suite IDE. This section provides a quick reference to parameters that can be configured at generation time. [Figure 4-1](#) shows the main Vivado Gamma LUT screen.

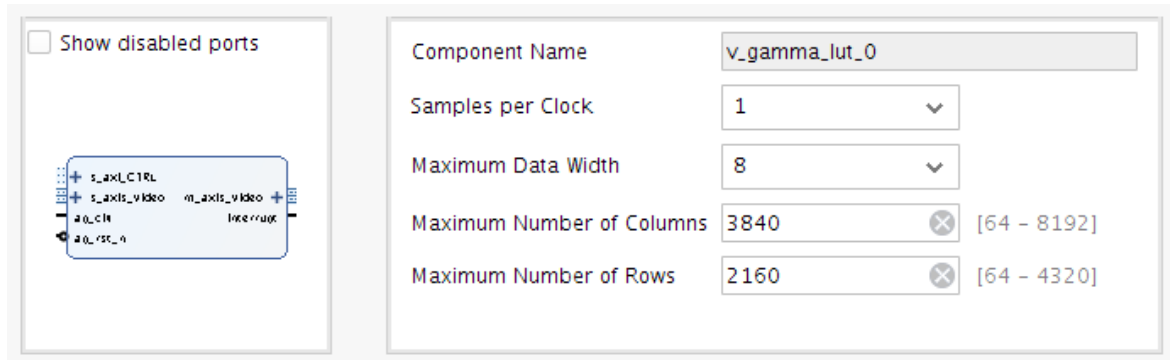


Figure 4-1: Gamma LUT Vivado IP Catalog IDE

The main screen displays a representation of the IP symbol on the left side, and the parameter assignments on the right side, which are described as follows:

- **Component Name:** The component name is used as the base name of output files generated for the module. Names must begin with a letter and must be composed from characters: a to z, 0 to 9 and "\_".  
*Note: The name v\_gamma\_lut\_v1\_0 is not allowed.*
- **Samples Per Clock:** Specifies the number of pixel processed per clock cycle. Permitted values are 1, 2, 4, and 8 samples per clock. This parameter determines the throughput of the IP. The more samples per clock, the larger throughput it provides. The larger throughput always needs more hardware resources.
- **Maximum Data Width:** Specifies the bit width of input samples. Permitted values are 8, 10, 12, and 16 bits. This parameter should match the Video Component Width of the video IP core connected to the slave AXI4-Stream video interface.
- **Maximum Number of Columns:** Specifies maximum video columns/pixels the IP core could produce at run time. Any video width that is less than the Maximum Number of Columns can be programmed through the AXI4-Lite control interface without regenerating the core.
- **Maximum Number of Rows:** Specifies the maximum video rows/lines the IP core can produce at run time. Any video height that is less than the Maximum Number of Rows can be programmed through AXI4-Lite control interface without regenerating core.

## 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

| Vivado IDE Parameter/Value  | User Parameter/Value | Default Value |
|-----------------------------|----------------------|---------------|
| <b>Top-Level Parameters</b> |                      |               |
| Samples per Clock           | SAMPLES_PER_CLOCK    | 1             |
| Maximum Number of Columns   | MAX_COLS             | 3840          |
| Maximum Number of Rows      | MAX_ROWS             | 2160          |
| Maximum Data Width          | MAX_DATA_WIDTH       | 8             |

## Output Generation

For details, see “Generating IP Output Products” in the *Vivado Design Suite User Guide: Designing with IP* (UG896) [Ref 5].

## Constraining the Core

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

### Required Constraints

The only constraints required are clock frequency constraints for the core clock, `ap_clk`. Paths from AXI4-Lite signals should be constrained with a `set_false_path`, causing setup and hold checks to be ignored for AXI4-Lite signals. These constraints are provided in the XDC constraints file included with the core.

### Device, Package, and Speed Grade Selections

This section is not applicable for this IP core.

### Clock Frequencies

This section is not applicable for this IP core.

## Clock Management

This section is not applicable for this IP core.

## Clock Placement

This section is not applicable for this IP core.

## Banking

This section is not applicable for this IP core.

## Transceiver Placement

This section is not applicable for this IP core.

## I/O Standard and Placement

This section is not applicable for this IP core.

---

## Simulation

For comprehensive information about Vivado simulation components, as well as information about using supported third party tools, see the *Vivado Design Suite User Guide: Logic Simulation* (UG900) [Ref 8].

---

## Synthesis and Implementation

This section contains information about synthesis and implementation in the Vivado Design Suite. For details about synthesis and implementation, see “Synthesizing IP” and “Implementing IP” in the *Vivado Design Suite User Guide: Designing with IP* (UG896) [Ref 5].

# Detailed Example Design

This chapter provides two example systems that include the Gamma LUT core; a simulation example design and a synthesizable example design. Both example designs highlight the following key system-level aspects of designing with the Gamma LUT core:

- Typical usage of Gamma LUT in conjunction with other cores and AXI master.
- Configuration of Gamma LUT registers on the fly.

The supported platforms are listed in [Table 5-1](#).

**Table 5-1: Supported Platforms**

| Development Boards | Additional Hardware | Processor             |
|--------------------|---------------------|-----------------------|
| KC705              | N/A                 | MicroBlaze™ processor |

To open the example project, perform the following steps:

1. Select the **Gamma LUT IP** from IP Catalog.
2. Double-click on the selected IP or right-click the IP and select **Customize IP** from the menu.
3. Configure the build-time parameters in the **Customize IP** window and click **OK**. The Vivado IDE generates an example design matching the build-time configuration.
4. In the **Generate Output Products** window, select **Generate** or **Skip**. If **Generate** is selected, the output products of the IP are generated after a brief moment.
5. Right-click **Gamma LUT** in the **Sources** panel and select **Open IP Example Design** from the menu.
6. In the **Open IP Example Design** window, select the example project directory and click **OK**. The Vivado® Design Suite software then runs automation to generate the example designs in the selected directory.

The generated project contains two example designs. [Figure 5-1](#) shows the Source panel of the example project. The synthesizable example block design, along with the top-level file, resides in the Design Sources catalog. Simulation example design files (including block design file and SystemVerilog test bench) are found under Simulation Sources.





Figure 5-1: Example Project Source Panel

## Simulation Example Design

The simulation example design contains the following video IP cores:

- Video Test Pattern Generator (TPG)
- Gamma LUT
- Video Timing Controller (VTC)
- AXI4-Stream to Video Output bridge

The design also contains a AXI Verification IP (VIP) core (to enable register programming) connected to an AXI interconnect. After all configurations are performed, the AXI VIP core starts the TPG, Gamma LUT, and Video Timing Controller cores. Because this design runs an RTL simulation, running large video frames can take a long time. Xilinx® recommends running a small video size for this example design. Width and height values, as well as other register settings, can be changed in the simulation test bench `v_gamma_lut_0_exdes_tb.sv` file.

The TPG core is in free-running mode after kickoff. It generates video stream pixels at the clock rate of `ap_clk`. The Gamma LUT core receives video frames from the AXI4-Stream slave interface and generates video output. The AXI4-Stream to Video Out core, working with Video Timing Controller, interfaces from the AXI4-Stream interface implementing a Video Protocol to a video source (parallel video data, video syncs, and blanks).

The example design verifies that the output port is locked from the AXI4-Stream to Video Out core. The locked port indicates that the output timing is locked to the output video. The example design indicates that the test has completed successfully if video lock is successfully detected.

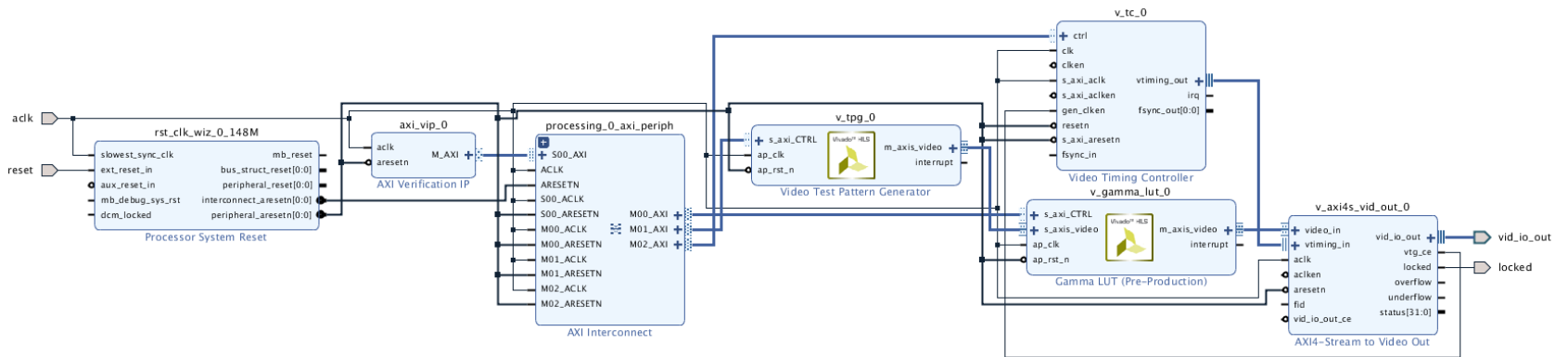


Figure 5-2: Simulation Example Design

# Synthesizable Example Design

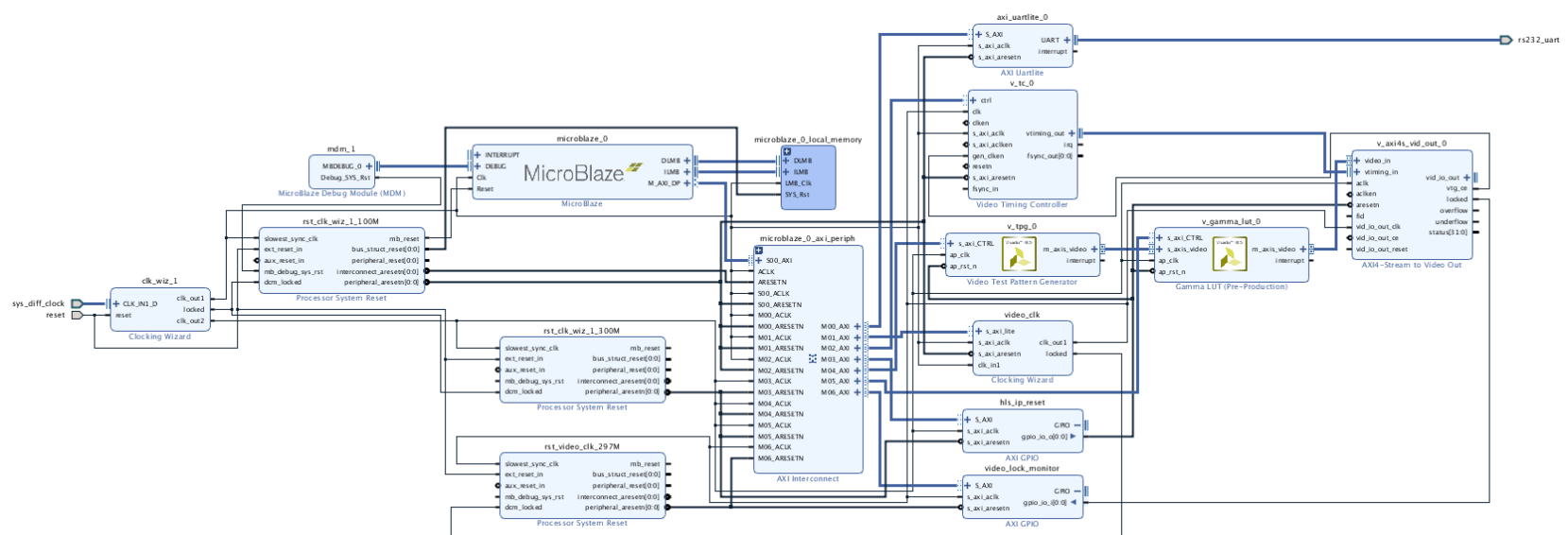


Figure 5-3: Synthesizable Example Design

The difference between the synthesizable example design and the simulation example design is the use of the MicroBlaze™ microprocessor instead of the AXI VIP core as the AXI master. The locked port of AXI4-Stream to Video Out is connected to the axi\_gpio\_lock core and the MicroBlaze processor polls the corresponding register for a sign that the test has passed.

The synthesizable example design requires both Vivado and Xilinx SDK tools. The first step is to run synthesis, implementation, and bitstream generation in Vivado. After all those steps are done, select **File -> Export -> Export Hardware**. In the window, select **Include bitstream**, select an export directory and click **OK**.

The remaining work is performed in Xilinx SDK tool. The Gamma LUT example design file can be found at the SDK directory:

```
(<install_directory>/<release>/data/embeddedsw/XilinxProcessorIPLib/drivers/
v_gamma_lut_v1_0/examples/
```

Example application design source files (contained within `examples` folder) are tightly coupled with the Gamma LUT example design available in the Vivado catalog.

The `vgamma_lut_example.tcl` file automates the process of generating the downloadable bit and `.elf` files from the provided example `.hdf` file. To run the provided Tcl script, perform the following steps:

1. Copy the exported example design `.hdf` file in the `examples` directory of the driver.
2. Launch the Xilinx Software Command-Line Tool (`xsct`) terminal.
3. Use `cd` to access the `examples` directory.
4. Source the Tcl file:

```
xsct%>source vgamma_lut_example.tcl
```

5. Execute the script:

```
xsct%>vgamma_lut_example <hdf_file_name.hdf>
```

The Tcl script performs the following actions:

- Creates workspace
- Creates HW project
- Creates BSP
- Creates application project
- Builds BSP and application project

After the process is complete, the required files are available in the following directories:

```
bit file -> vgamma_lut_example.sdk/vgamma_lut_example_hw_platform folder
elf file -> vgamma_lut_example.sdk/vgamma_lut_example_design/{Debug/Release} folder
```

Next, perform the following steps to run the software application:



---

**IMPORTANT:** To do so, make sure that the hardware is powered on and a Digilent Cable or an USB Platform Cable is connected to the host PC. Also, ensure that a USB cable is connected to the UART port of the KC705 board.

---

1. Launch SDK.
2. Set workspace to `vgamma_lut_example.sdk` folder in prompted window. The SDK project opens automatically. If a welcome page shows up, close that page.
3. Download the bitstream into the FPGA by selecting **Xilinx Tools > Program FPGA**. The Program FPGA dialog box opens.
4. Ensure that the Bitstream field shows the bitstream file generated by the Tcl script, and then click **Program**.  
**Note:** The DONE LED on the board turns green if the programming is successful.
5. A terminal program (HyperTerminal or PuTTY) is needed for UART communication. Open the program, choose the appropriate port, set the baud rate to 115200, and establish a serial port connection.
6. Select and right-click the `vgamma_lut_example_design` application in the Project Explorer panel.
7. Select **Run As > Launch on Hardware (System Debugger)**.
8. Select Binaries and Qualifier in window and click **OK**. The example design test results are shown in terminal program.

For more information, visit [www.xilinx.com/tools/sdk.htm](http://www.xilinx.com/tools/sdk.htm).

When executed on the board, the example application performs the following actions:

- Programs the video clock generator to 1080p@60Hz
- Programs TPG and Gamma LUT to 1080p@60Hz
- Checks for video lock and reports the status (PASS/FAIL) on UART
- Repeats steps 1-3 for 4KP@30Hz and 4KP@60Hz

# Verification, Compliance, and Interoperability

---

## Simulation

A highly parameterizable test bench was used to test the Gamma LUT core in Vivado® HLS. Testing included the following:

- Register accesses
  - Processing multiple frames of data
  - Varying IP throughput and pixel data width
  - Testing of various frame sizes
  - Varying parameter settings
- 

## Hardware Testing

The Gamma LUT core has been validated in hardware at Xilinx to represent a variety of parameterizations, including the following:

- A test design was developed for the core that incorporated a MicroBlaze™ processor, AXI4-Lite interconnect and various other peripherals. The MicroBlaze processor was responsible for:
  - Programming the video clock to match tested video resolution
  - Configuring the Gamma LUT core with different resolutions
  - Launching the test
  - Reporting the Pass/Fail status of the test and any errors that were found

---

## Interoperability

The core slave (input) AXI4-Stream interface can work directly with any core that produces RGB or YUV 444 video data.

# Upgrading

This appendix contains information about upgrading to a more recent version of the IP core. This appendix does not apply to this core.



# Debugging

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

---

## Finding Help on Xilinx.com

To help in the design and debug process when using the Gamma LUT, the [Xilinx Support web page](#) (Xilinx Support web page) contains key resources such as product documentation, release notes, answer records, information about known issues, and links for opening a Technical Support Web Case.

### Documentation

This product guide is the main document associated with the Gamma LUT. 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 core are listed below, and can also 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.

### Answer Records for the Gamma LUT Core

[AR 68768](#)

## 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](#).

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## Debug Tools

There are many tools available to address Gamma LUT core 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)

See the *Vivado Design Suite User Guide: Programming and Debugging* (UG908) [Ref 6].

---

## 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 Vivado debug feature for debugging the specific problems.

### General Checks

Ensure that all the timing constraints for the core were properly incorporated from the example design and that all constraints were met during implementation.

- Does it work in post-place and route timing simulation? If problems are seen in hardware but not in timing simulation, this could indicate a PCB issue. Ensure that all clock sources are active and clean.
- If you are using MMCMs in the design, ensure that all MMCMs have obtained lock by monitoring the `LOCKED` port.

# Additional Resources

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## Xilinx Resources

For support resources such as Answers, Documentation, Downloads, and Forums, see [Xilinx Support](#).

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## Documentation Navigator and Design Hubs

Xilinx® Documentation Navigator provides access to Xilinx documents, videos, and support resources, which you can filter and search to find information. To open the Xilinx Documentation Navigator (DocNav):

- From the Vivado® IDE, select **Help > Documentation and Tutorials**.
- On Windows, select **Start > All Programs > Xilinx Design Tools > DocNav**.
- At the Linux command prompt, enter `docnav`.

Xilinx Design Hubs provide links to documentation organized by design tasks and other topics, which you can use to learn key concepts and address frequently asked questions. To access the Design Hubs:

- In the Xilinx Documentation Navigator, click the **Design Hubs View** tab.
- On the Xilinx website, see the [Design Hubs](#) page.

**Note:** For more information on Documentation Navigator, see the [Documentation Navigator](#) page on the Xilinx website.

## References

These documents provide supplemental material useful with this user guide:

1. *Vivado AXI Reference Guide* ([UG1037](#))
2. *AXI4-Stream Video IP and System Design Guide* ([UG934](#))
3. *AXI Reference Guide* ([UG761](#))
4. *ISE to Vivado Design Suite Migration Guide* ([UG911](#))
5. *Vivado Design Suite User Guide: Designing with IP* ([UG896](#))
6. *Vivado Design Suite User Guide: Programming and Debugging* ([UG908](#))
7. *Vivado Design Suite User Guide: Getting Started* ([UG910](#))
8. *Vivado Design Suite User Guide: Logic Simulation* ([UG900](#))
9. *Vivado Design Suite User Guide: Designing IP Subsystems using IP Integrator* ([UG994](#))

## Revision History

The following table shows the revision history for this document.

| Section                       | Revision Summary  |
|-------------------------------|---|
| <b>12/05/2018 Version 1.0</b> |   |
| <a href="#">Table 2-4</a>     | Updated the register addresses for Gamma look-up table 0, Gamma look-up table 1, and Gamma look-up table 2. |
| <b>10/04/2017 Version 1.0</b> |   |
| General updates               | Initial Xilinx release.   |

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