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1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 1.0

The first publication of this document.
2 Introduction

A camera sensor converts the light intensity of a pixel into equivalent digital value. The digital value is directly proportional to the light intensity of a pixel and hence has a linear relationship. However, a human eye perceives the images as a logarithmic function of intensity instead of a linear function. If the images from a camera sensor are directly displayed on a display device, then the scene will appear unnatural because of the differences between the camera sensor and human eye perception. To compensate this, the image from the camera sensor goes through the gamma correction.

Gamma correction uses an exponent function to compensate for the logarithmic perception by using the below equation:

\[ D_{\text{out}} = (D_{\text{in}})^\gamma \]

where,

- \( D_{\text{out}} \) represents output image data (RGB). Represented in the range of 0 to 1.
- \( D_{\text{in}} \) represents input image data (RGB). Represented in the range of 0 to 1.
- \( \gamma \) represents the gamma correction factor. A fixed gamma correction factor of 0.4545 corresponding to a gamma of 2.2 is implemented in the IP.

The Gamma correction IP is implemented using a LUT for exponent function.

The width of the input data determines the number of entries in the LUT. For example, 8-bit input data would require \( 2^8 \) (256) entries in the LUT.

This section describes the inputs and outputs and configuration parameters of the Gamma Correction IP.

2.1 Key Features

- LUT based gamma correction
- Fixed gamma factor of 2.2
- Supports data width of 8 and 10

2.2 Supported Families

- PolarFire® SoC
- PolarFire®
- RTG4™
- IGLOO®2
- SmartFusion®2
2.3 Inputs and Outputs

*Figure 1* • Inputs and Outputs

The following table lists the input and output ports of the Gamma Correction IP.

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Direction</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS_CLK_I</td>
<td>Input</td>
<td>1 bit</td>
<td>System clock.</td>
</tr>
<tr>
<td>RESETN_I</td>
<td>Input</td>
<td>1 bit</td>
<td>Active low asynchronous reset signal.</td>
</tr>
<tr>
<td>DATA_VALID_I</td>
<td>Input</td>
<td>1 bit</td>
<td>Input data valid signal. This signal should be asserted when the data is valid.</td>
</tr>
<tr>
<td>RED_I</td>
<td>Input</td>
<td>8 bits</td>
<td>Input Red pixel data.</td>
</tr>
<tr>
<td>GREEN_I</td>
<td>Input</td>
<td>8 bits</td>
<td>Input Green pixel data.</td>
</tr>
<tr>
<td>BLUE_I</td>
<td>Input</td>
<td>8 bits</td>
<td>Input Blue pixel data.</td>
</tr>
<tr>
<td>DATA_VALID_O</td>
<td>Output</td>
<td>1 bit</td>
<td>Output data valid signal. This signal is asserted when the output data is valid.</td>
</tr>
<tr>
<td>RED_O</td>
<td>Output</td>
<td>8 bits</td>
<td>Output Red pixel data.</td>
</tr>
<tr>
<td>GREEN_O</td>
<td>Output</td>
<td>8 bits</td>
<td>Output Green pixel data.</td>
</tr>
<tr>
<td>BLUE_O</td>
<td>Output</td>
<td>8 bits</td>
<td>Output Blue pixel data.</td>
</tr>
</tbody>
</table>

2.4 Configuration Parameters

The following table lists the configuration parameters used in the hardware implementation of the Gamma correction. These parameters are generic and can be varied based on the application requirement.

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_DATA_WIDTH</td>
<td>Represents bitwidth of input and output data. Current version supports 8-bit and 10-bit input and output data.</td>
</tr>
</tbody>
</table>
3  Testbench

A testbench is provided to check the functionality of the Gamma Correction IP. To ensure that the testbench works correctly, the configuration parameters listed in Table 3 must be configured at the beginning of the testbench file.

**Table 3 • Testbench Configuration Parameters**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKPERIOD</td>
<td>Clock period</td>
</tr>
<tr>
<td>g_DATAWIDTH</td>
<td>Width of each pixel</td>
</tr>
<tr>
<td>HEIGHT</td>
<td>Vertical resolution</td>
</tr>
<tr>
<td>WIDTH</td>
<td>Horizontal resolution</td>
</tr>
<tr>
<td>IMAGE_FILE_NAME</td>
<td>Input image file</td>
</tr>
</tbody>
</table>

3.1  License

Gamma-Correction clear RTL is license locked and the obfuscated RTL available for free.

3.1.1  Obfuscated

Complete RTL code is provided for the core, allowing the core to be instantiated with the SmartDesign tool. Simulation, synthesis, and layout can be performed within Libero® System-on-Chip (SoC). The RTL code for the core is obfuscated.

3.1.2  RTL

Complete RTL source code is provided for the core.

The following steps describe how to simulate the core using the testbench. The packaged testbench will gamma correct an input image.

1. In the Design Flow window, expand Create Design. Right-click Create SmartDesign testbench and click Run, as shown in the following figure.

Figure 2 • Design Flow

SmartDesign testbench is created, and a canvas appears to the right of the Design Flow pane.
2. In the **Libero SoC Catalog (View > Windows > Catalog)**, expand **Solutions-Video**, and drag the **Gamma-Correction** IP core onto the SmartDesign testbench canvas.

![Libero SoC Catalog](image)

**Figure 3 • Libero SoC Catalog**

3. Select the default component name and click **OK**.

4. In the **Gamma-Correction Configurator** GUI window, update the G_DATA_WIDTH and click **OK**.

![Configurator](image)

**Figure 4 • Configurator**

5. On Design Hierarchy tab, right-click **GAMMA_CORRECTION_C0** and click **Set As Root**.
6. Select all the ports on the GAMMA_CORRECTION_C0 instance, right-click, and select **Promote to Top Level**, as shown in the following figure.

   *Figure 5 • GAMMA_CORRECTION_C0 Instance*

   ![GAMMA_CORRECTION_C0 Instance](image)

   **Figure 6 • SmartDesign Toolbar**

   ![SmartDesign Toolbar](image)

7. Click **Generate Component** from the SmartDesign toolbar.
8. Go to the Files tab and select **simulation > Import Files...**, as shown in the following figure.

   *Figure 7 • Import Files*

   ![Import Files](image)
9. Import the Input Image file "CFA_RGB_in.txt" from the following path: ..\<Project_name>\component\Microsemi\SolutionCore\Gamma-Correction\1.0.0\Stimulus. To import a different file, browse the folder that contains the required file, and click Open. The imported file is listed under simulation as shown in the following figure.

Figure 8 • Simulation

10. On Stimulus Hierarchy tab, right-click gamma_correction_test testbench file and click Open Interactively from Simulate Pre-Synth Design.

Figure 9 • Stimulus Hierarchy
The ModelSim tool appears with the test bench file loaded onto it, as shown in the following figure.

**Figure 10 • ModelSim tool**

If the simulation is interrupted because of the runtime limit in the DO file, use the `run -all` command to complete the simulation. By default, the output image file is placed in the `Files/simulation` directory and uses the `CFA_RGB_out.txt`. 
4 Simulation Results

4.1 Timing Diagram

The following is the timing diagram for Gamma Correction IP showing video data and output image.

Figure 11 • Gamma Correction IP

4.2 Input Image

Figure 12 • Input Image
4.3 Output Image

Figure 13 • Output Image
Gamma correction is implemented on PolarFire FPGA (MPF500T-1FCG1152I package). The following table shows the resource utilization report after synthesis.

**Table 4 • Gamma Correction IP Resource Utilization**

<table>
<thead>
<tr>
<th>Gamma Correction IP</th>
<th>LUT</th>
<th>DFF</th>
<th>RAM1K20</th>
<th>MACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_DATA_WIDTH=8</td>
<td>354</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G_DATA_WIDTH=10</td>
<td>1439</td>
<td>32</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>