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| Digital System Design SS2024 |
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| Lab 1: Design and Test of VHDL IP |
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# Introduction

Test a HDMI display controller, designed to display images captured by a camera. Data of the HDMI display controller is finally sent to the on-board HDMI transmitter chip. The camera is getting emulated by another VHDL model.

Objectives:

* Study of the top-level RTL design
* VHDL design of the Camera Emulator
* Simulation of the Camera Emulator
* Test of HDMI Display Controller on ZedBoard

## Part-1

### Task-1

Q1. Describe the meaning of all output signals of HDMI\_V1!! Consider that those output signals are inputs to the HDMI transmitter ADV7511. Do research on ADV7511 of ZedBoard. Use a table format with two columns: signal name and description!

Elaboration:

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| **Signal Name** | **Description** |
| Data\_out [15:0] | * 16-bit Data output of frame buffer |
| HDMI\_CLK | * A clock of 25MHz from vga\_pll\_zedboard |
| config\_done | * CEC data signal. Supports CMOS logic levels from 1.8V to 5V * One of the outputs of ov7670\_controller * A LED to show when config is finished |
| PwDn | * Power saver mode. One of the outputs of ov7670\_controller (transfers registers to the camera over an I2C like bus) * A LED shows if it is at the power saver mode |
| de | * Data Enable signal input for Digital Video. Supports typical CMOS logic levels from 1.8V up to 3.3V * One of the outputs of vga\_controller and acts as input to Video data capture of the HDMI transmitter ADV7511 * Display enables where '1' is the display time and '0' is the blanking time |
| h\_sync | * Horizontal Sync Pulse input. Supports typical CMOS logic levels from 1.8V up to 3.3V * One of the outputs of vga\_controller and acts as input to Video data capture of the HDMI transmitter ADV7511 |
| v\_sync | * Vertical Sync Pulse input. Supports typical CMOS logic levels from 1.8V up to 3.3V * One of the outputs of vga\_controller and acts as input to Video data capture of the HDMI transmitter ADV7511 |
| siod\_hdmi | * Serial Port Data I/O. Supports CMOS logic levels from 1.8V to 3.3V * This pin serves as the serial port data I/O slave for register access |
| sioc\_hdmi | * Serial Port Data Clock input. Supports CMOS logic levels from 1.8V to 3.3V * Can write to the registers |
| xClk | * Clk Driver for OV7670 camera * One of the outputs of ov7670\_controller |
| Reset | * Always '1' for normal mode * One of the outputs of ov7670\_controller |

### Task-2

Q1. The component IMG\_GENERATOR emulates the camera. Do research on OV7670 camera (data sheet). Describe each signal provided by the camera (assume a resolution setting of 640x480 and an output format of Y/Cb/Cr 4:2:2) and compare with the output ports of IMG\_GENERATOR! Use a table format with two columns: signal name and description!

Elaboration:

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| **Signal Name** | **Description** |
| cam\_pwdn | * Power Down Mode Selection * 0: Normal mode 1: Power down mode |
| cam\_reset | * Clears all registers and resets them to their default values. * 0: Normal mode 1: Reset mode |
| cam\_sioc | * SCCB serial interface clock input |
| cam\_xclk | * System clock input |
| cam\_data[7:0] | * 8-bit output of Pixel\_Generator * YUV video component output |
| cam\_href | * HREF output * It is responsible for synchronizing each line of the image frame |
| cam\_pclk | * Pixel clock output |
| cam\_siod | * SCCB serial interface data I/O |
| cam\_vsync | * Vertical sync output * It is responsible for synchronizing an entire image frame on the screen |

## Part-2

### Task-1

### Task-2

Q1. In Pixel\_Generator.vhd we need to specify Y, CB and CR. Use VHDL constant with data type STD\_LOGIC\_VECTOR (7 downto 0)! Generate blue pixels!

Elaboration:

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| library IEEE;  use IEEE.STD\_LOGIC\_1164.ALL;  entity Pixel\_Generator is Port (  pclk : in STD\_LOGIC; -- Pixel clock input  href : in STD\_LOGIC; -- Horizontal synchronization input  vsync : in STD\_LOGIC; -- Vertical synchronization input  data : out STD\_LOGIC\_VECTOR (7 downto 0) -- Output pixel data  );  end Pixel\_Generator;  architecture Behavioral of Pixel\_Generator is  -- Constants representing blue pixel values in YCbCr format  constant y\_blue : STD\_LOGIC\_VECTOR (7 downto 0) := x"29";  constant cb\_blue : STD\_LOGIC\_VECTOR (7 downto 0) := x"F0";  constant cr\_blue : STD\_LOGIC\_VECTOR (7 downto 0) := x"6E";  -- Counter for horizontal pixel position  signal count : integer range 0 to 639 := 0;    begin  -- Process for generating blue pixels on falling edge of pixel clock  blue\_pixel\_generation : process(pclk)  begin  if falling\_edge(pclk) then  -- Switch case to determine which component of YCbCr to output  case count mod 4 is  when 0 =>  data <= cb\_blue; -- Output Cb component  when 1 | 3 =>  data <= y\_blue; -- Output Y component  when others =>  data <= cr\_blue; -- Output Cr component  end case;  -- Increment horizontal pixel position counter  if count = 639 then  count <= 0; -- Reset counter at end of line  else  count <= count + 1; -- Increment counter  end if;  end if;  end process blue\_pixel\_generation;  end Behavioral; |

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| **Colors** | **Y-Cb-Cr Value** |
| Black | (16,128,128) |
| White | (235,128,128) |
| Red | (82,90,240) |
| Green | (145,54,34) |
| Blue | (41,240,110) |
| Yellow | (210,16,146) |
| Cyan | (170,166,16) |
| Magenta | (107,202,222) |

# References

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| [1] | "VHDL Programming by Example" by Douglas L. Perry |
| [2] | "VHDL: Analysis and Modeling of Digital Systems" by Zainalabedin Navabi |
| [3] | "FPGA Prototyping by VHDL Examples: Xilinx MicroBlaze MCS SoC" by Pong P. Chu |
| [4] | "The Zynq Book" by Louise H. Crockett et al. |
| [5] |  |