Tutorial of displaying pixels on VGA monitor

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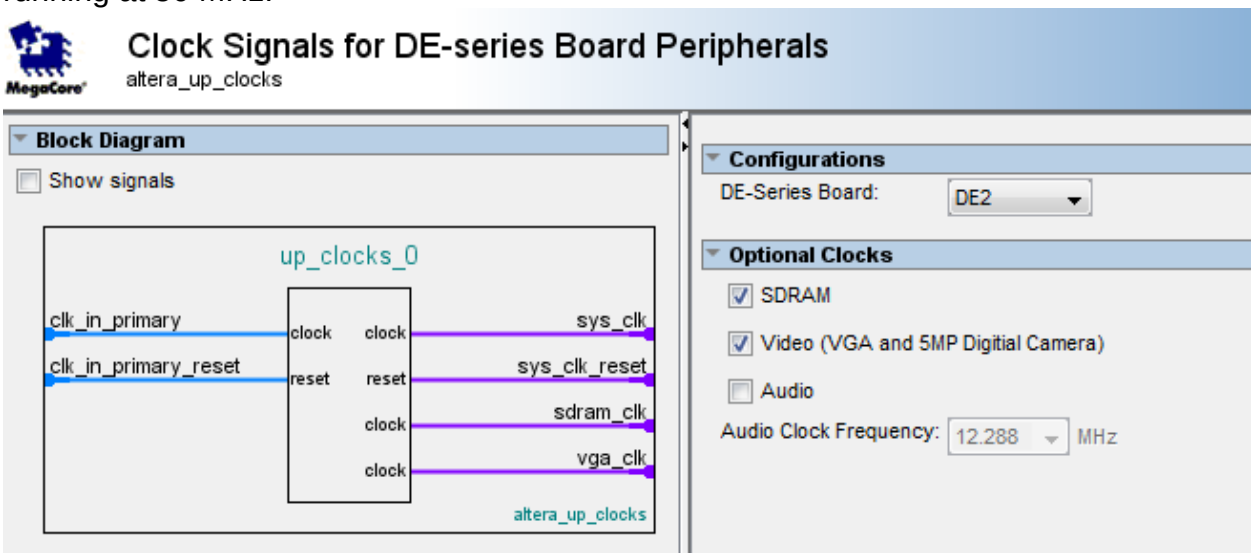
Introduction

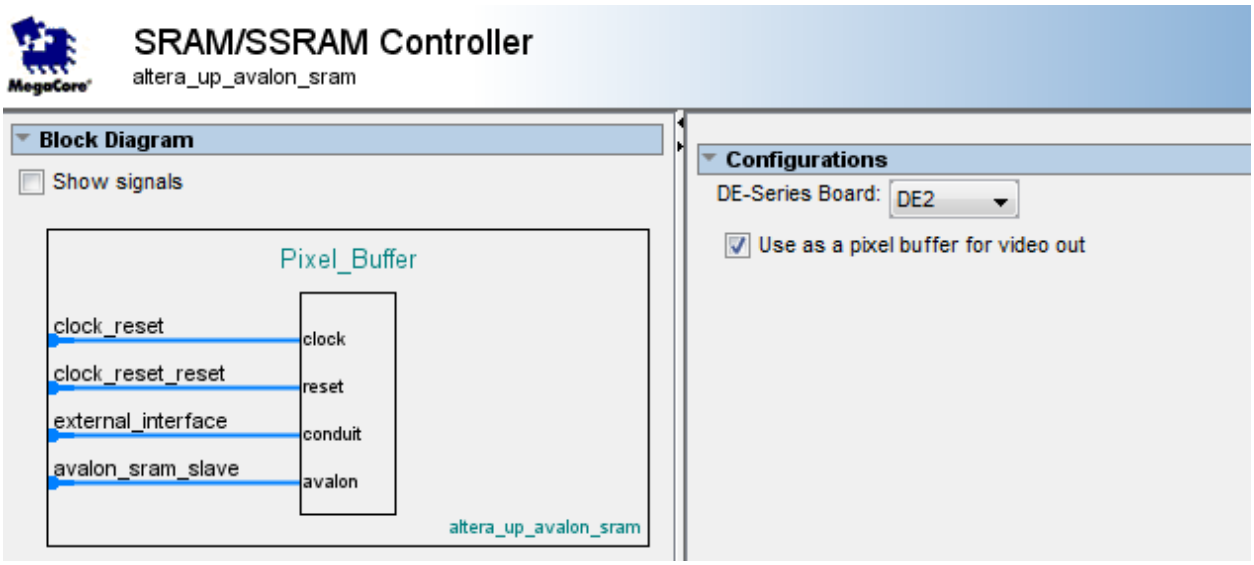
This tutorial will demonstrate how to connect a VGA monitor with Altera DE2 board, and display pixels on VGA monitor.

Procedure

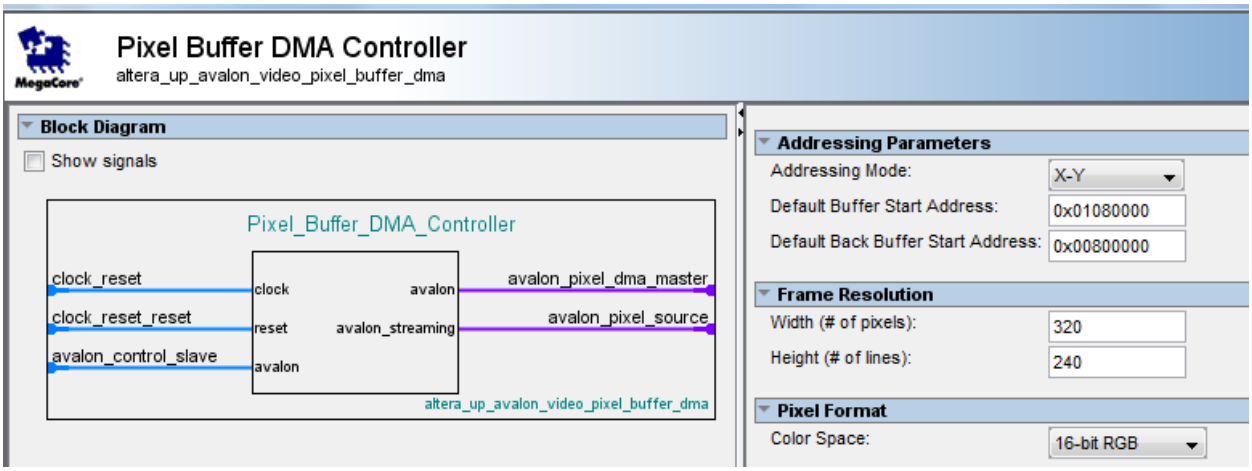
1. Use Qsys to create an embedded system, and we need SRAM/SSRAM Controller, Pixel Buffer DMA Controller, RGB Resampler, Scaler, Dual-Clock FIFO, VGA Controller. In reference section, the *Video.h*explained the functionalities of the above components on page3 in details.
2. Clock signals for DE-series Board Peripherals
   On DE2 board, different components have different required running clock signals. For example, VGA controller is running at 25 MHz, but the CPU is running at 50 MHz.



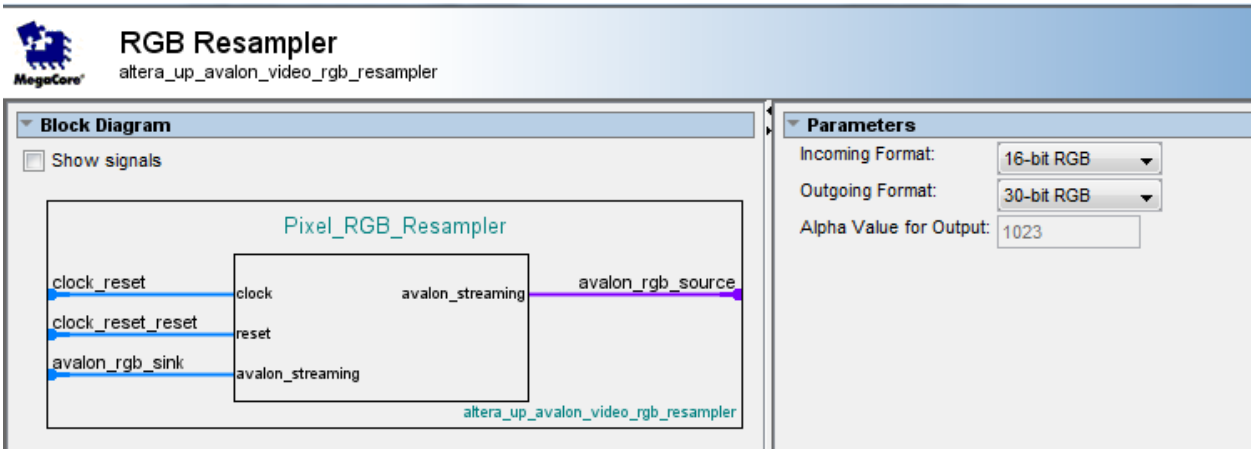
3. SRAM/SSRAM Controller
   We need a pixel buffer working with Pixel Buffer DMA Controller. Check “Use as a pixel buffer for video out”.



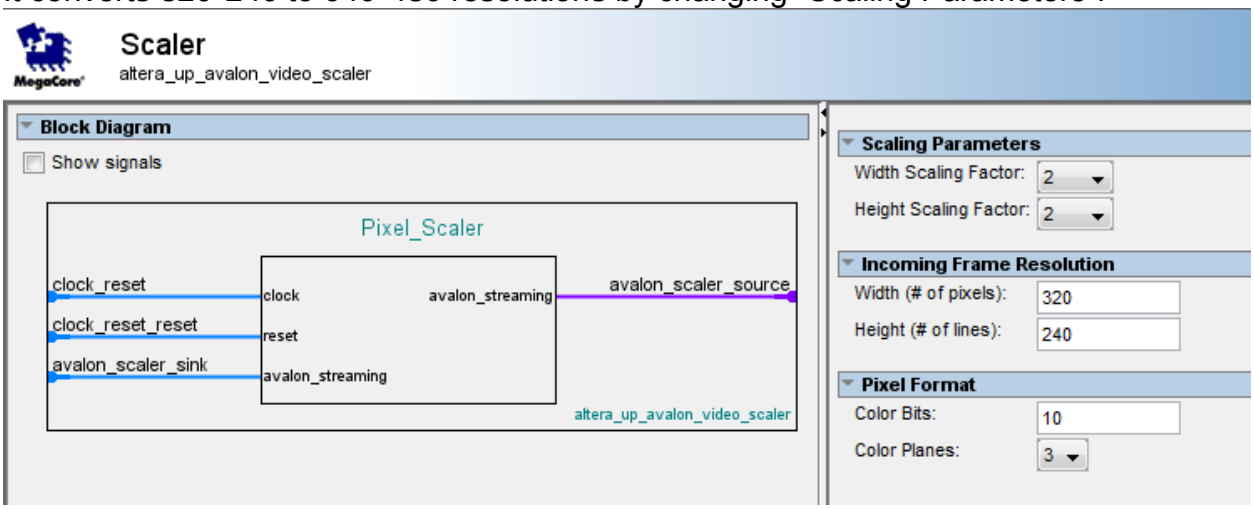
4. Pixel Buffer DMA Controller
   The “Default Buffer Start Address” is the base address of the pixel buffer which is SRAM in our design. And the “Default Back Buffer Start Address” is the base address of SDRAM.The Pixel Buffer DMA Controller will read image pixels from memory. In memory, the image is stored as 16 bit RGB, and 320*240 resolutions.



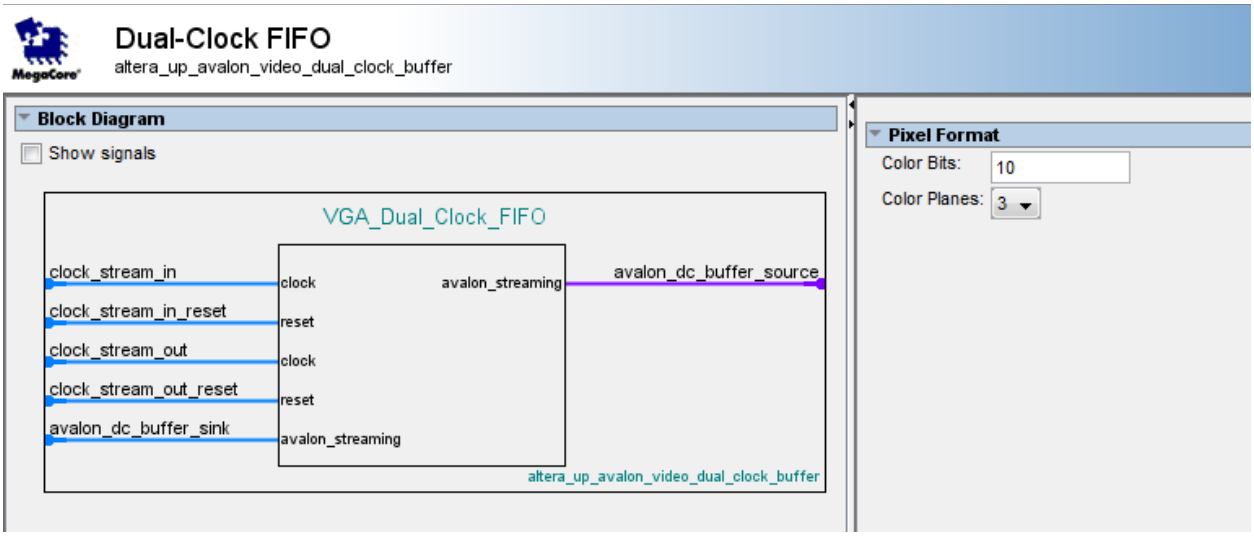
5. RGB Resampler
   It converts 16 bit/pixel to 30 bit/pixel, but remain 320*240 resolution formats.



6. Scaler
It converts 320*240 to 640*480 resolutions by changing “Scaling Parameters”.



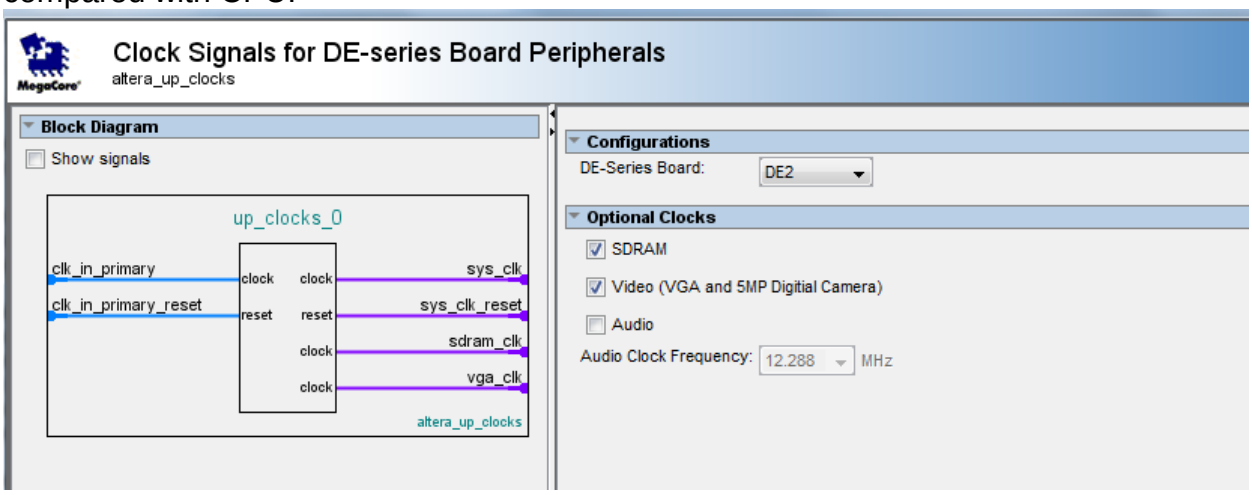
7. Dual-Clock FIFO
The clock_stream_out is running at 25 MHz, and the clock_stream_in is running 50 MHz.



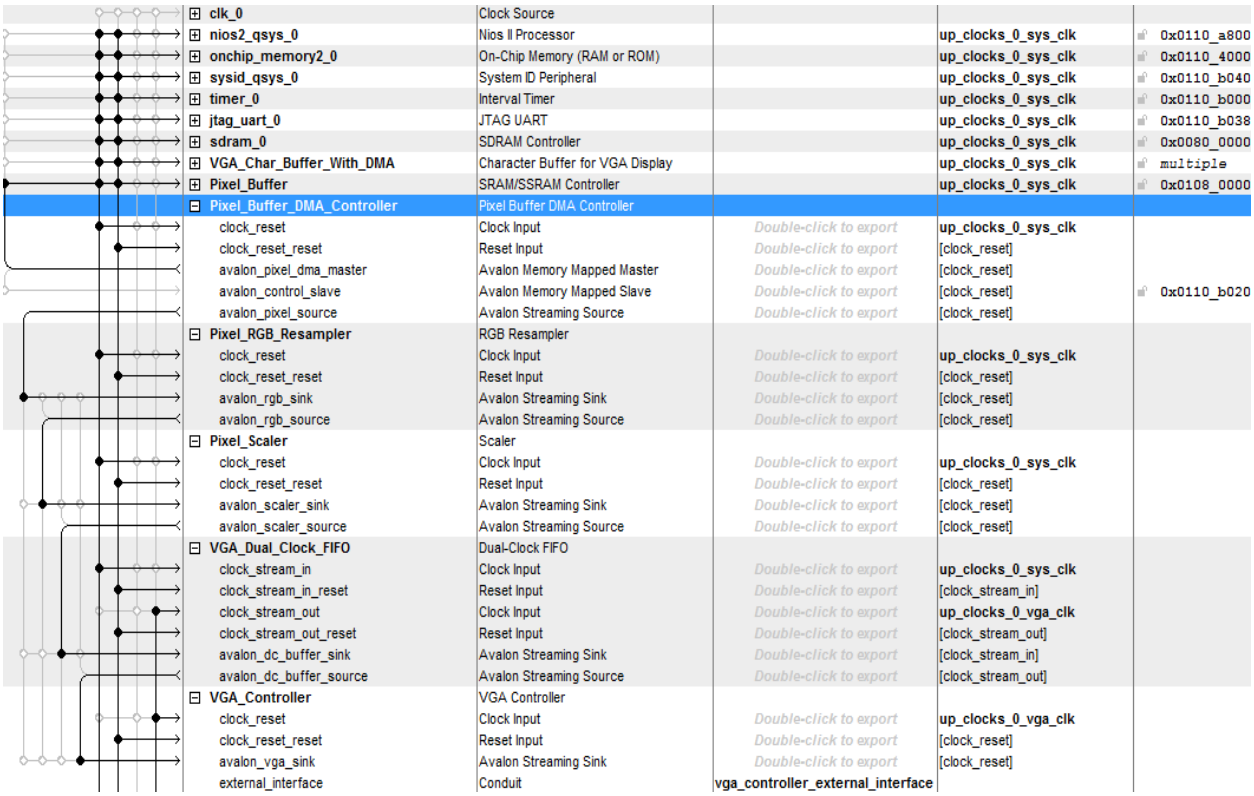
8. VGA Controller

The clock_reset is running at 25 MHz. external_interface is conduit and is exported.

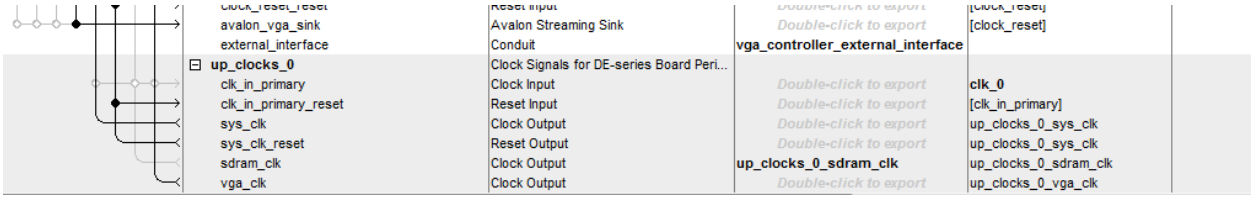
9. Clock Signals for DE-series Board Peripherals
   In our project, we have SDRAM and Video running at different clock frequencies. And sdram_clk is exported for SDRAM because SDRAM is running some delay compared with CPU.



10. The final looking should be like the following:



clk_0	Clock Source			
nios2_qsys_0	Nios II Processor		up_clocks_0_sys_clk	0x0110_a800
onchip_memory2_0	On-Chip Memory (RAM or ROM)		up_clocks_0_sys_clk	0x0110_4000
sysid_qsys_0	System ID Peripheral		up_clocks_0_sys_clk	0x0110_b040
timer_0	Interval Timer		up_clocks_0_sys_clk	0x0110_b000
jtag_uart_0	JTAG UART		up_clocks_0_sys_clk	0x0110_b038
sdram_0	SDRAM Controller		up_clocks_0_sys_clk	0x0080_0000
VGA_Char_Buffer_With_DMA	Character Buffer for VGA Display		up_clocks_0_sys_clk	multiple
Pixel_Buffer	SRAM/SSRAM Controller		up_clocks_0_sys_clk	0x0108_0000
Pixel_Buffer_DMA_Controller	Pixel Buffer DMA Controller			
clock_reset	Clock Input	Double-click to export	up_clocks_0_sys_clk	
clock_reset_reset	Reset Input	Double-click to export	[clock_reset]	
avalon_pixel_dma_master	Avalon Memory Mapped Master	Double-click to export	[clock_reset]	
avalon_control_slave	Avalon Memory Mapped Slave	Double-click to export	[clock_reset]	0x0110_b020
avalon_pixel_source	Avalon Streaming Source	Double-click to export	[clock_reset]	
Pixel_RGB_Resampler	RGB Resampler			
clock_reset	Clock Input	Double-click to export	up_clocks_0_sys_clk	
clock_reset_reset	Reset Input	Double-click to export	[clock_reset]	
avalon_rgb_sink	Avalon Streaming Sink	Double-click to export	[clock_reset]	
avalon_rgb_source	Avalon Streaming Source	Double-click to export	[clock_reset]	
Pixel_Scaler	Scaler			
clock_reset	Clock Input	Double-click to export	up_clocks_0_sys_clk	
clock_reset_reset	Reset Input	Double-click to export	[clock_reset]	
avalon_scaler_sink	Avalon Streaming Sink	Double-click to export	[clock_reset]	
avalon_scaler_source	Avalon Streaming Source	Double-click to export	[clock_reset]	
VGA_Dual_Clock_FIFO	Dual-Clock FIFO			
clock_stream_in	Clock Input	Double-click to export	up_clocks_0_sys_clk	
clock_stream_in_reset	Reset Input	Double-click to export	[clock_stream_in]	
clock_stream_out	Clock Input	Double-click to export	up_clocks_0_vga_clk	
clock_stream_out_reset	Reset Input	Double-click to export	[clock_stream_out]	
avalon_dc_buffer_sink	Avalon Streaming Sink	Double-click to export	[clock_stream_in]	
avalon_dc_buffer_source	Avalon Streaming Source	Double-click to export	[clock_stream_out]	
VGA_Controller	VGA Controller			
clock_reset	Clock Input	Double-click to export	up_clocks_0_vga_clk	
clock_reset_reset	Reset Input	Double-click to export	[clock_reset]	
avalon_vga_sink	Avalon Streaming Sink	Double-click to export	[clock_reset]	
external_interface	Conduit	vga_controller_external_interface		



11. Toplevel file in VHDL
    I exported VGA Controller external_interface, so in the toplevel file I added 8 more outputs:

```
-- VGA Controller
VGA_R : OUT STD_LOGIC_VECTOR (9 downto 0);
VGA_B : OUT STD_LOGIC_VECTOR (9 downto 0);
VGA_G : OUT STD_LOGIC_VECTOR (9 downto 0);
VGA_CLK: OUT STD_LOGIC;
VGA_BLANK: OUT STD_LOGIC;
VGA_HS: OUT STD_LOGIC;
VGA_VS: OUT STD_LOGIC;
VGA_SYNC: OUT STD_LOGIC
```

    Then port map those 8 outputs signals:

```
-- VGA Controller
   vga_controller_external_interface_CLK   => VGA_CLK,    -- vga_contro
   vga_controller_external_interface_HS    => VGA_HS,     --
   vga_controller_external_interface_VS    => VGA_VS,     --
   vga_controller_external_interface_BLANK => VGA_BLANK,  --
   vga_controller_external_interface_SYNC  => VGA_SYNC,   --
   vga_controller_external_interface_R     => VGA_R,      --
   vga_controller_external_interface_G     => VGA_G,      --
   vga_controller_external_interface_B     => VGA_B,       --
```

12. Compile, Program Device, Nios II Software Build Tools for Eclipse
13. Create a new “Nios II Application and BSP from Template”.
14. You need to include the file “altera_up_avalon_video_pixel_buffer_dma.h” to use some functions inside.
    1). Open the pixel buffer device

```
// Open the pixel buffer device
pixel_buf_dev = alt_up_pixel_buffer_dma_open_dev(
        "/dev/Pixel_Buffer_DMA_Controller");
if (pixel_buf_dev == NULL)
{
    printf("Error: could not open pixel buffer device \n");
} else
{
    printf("Opened pixel buffer device \n");
}
```

    2). There are two buffers, primary buffer which is the SRAM and back buffer which is the SDRAM in our project. You can also assign your own buffer addresses. By choosing primary buffer, the data in primary buffer will be sent to VGA controller. By choosing back buffer, the data in back buffer will be sent to VGA controller. VGA Controller is responsible to deliver image pixels to VGA monitor to display. So make sure correct buffer data will be sent.

Check if the pixel buffer device has the primary buffer address. If not, then change to the primary buffer address. “p_addrs” is the primary buffer base address.

```
// Make sure the pixel buffer device has the primary buffer address
if (pixel_buf_dev->buffer_start_address != p_addrs)
{
    alt_up_pixel_buffer_dma_change_back_buffer_address(pixel_buf_dev, p_addrs);
    alt_up_pixel_buffer_dma_swap_buffers(pixel_buf_dev);
}
```

3). Clean the screen. The parameter “0” means clear the primary buffer, and “1”means clear back buffer.

```
// Clear the screen
alt_up_pixel_buffer_dma_clear_screen(pixel_buf_dev,0);
```

4). The function “alt_up_pixel_buffer_dma_draw(pixel_buf_dev, color, x, y);” is working on back buffer, if you want to use this function to display pixels on VGA monitor, then choosing the back buffer. The function “alt_up_pixel_buffer_dma_swap_buffers(pixel_buf_dev);” is used to swap the buffer that will be sent to VGA controller.

```
// "alt_up_pixel_buffer_dma_draw" is working on back buffer, so we need sent
// back buffer to VGA controller
alt_up_pixel_buffer_dma_swap_buffers(pixel_buf_dev);
for (y = 0; y <480; y++)
{
    for (x = 0; x<640; x++)
    {
        // Draw pixels to VGA monitor
        error = alt_up_pixel_buffer_dma_draw(pixel_buf_dev, color, x, y);
        if (error == 1)
        {
            printf ("Error while drawing. The position is (%d,%d) \n", x,y);
        }
    }
}
```

5). In some functions, there is a parameter to select the back buffer or the primary buffer. You don’t have to change it by yourself again. For example,

“`void alt_up_pixel_buffer_dma_draw_box(alt_up_pixel_buffer_dma_dev *pixel_buffer, int x0, int y0, int x1, int y1, int color, int backbuffer);`”

“`voidalt_up_pixel_buffer_dma_draw_hline(alt_up_pixel_buffer_dma_dev *pixel_buffer, int x0, int x1, int y, int color, int backbuffer);`”

The parameter “backbuffer” set to 1 is to select back buffer, and 0 is to select primary buffer.

Reference

Video.h file:///C:/altera/12.1sp1/ip/University_Program/Audio_Video/Video/doc/Video.pdf