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| System On Chip (ELEC-4475-01-F15) |
| Lab 5 |
| Lab Report |
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| **11/18/2015** |

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# Introduction

The ultimate purpose to all of the lab assignments for the System on Chip course is to create a simple video game gradually using specifications similar to that of the Nintendo Entertainment System (NES), released in the 1980s. Each lab assignment related to one aspect of the FPGA SoC. Throughout this course, we learn how to use Xilinx software to program on the Spartan 3E FPGA board.

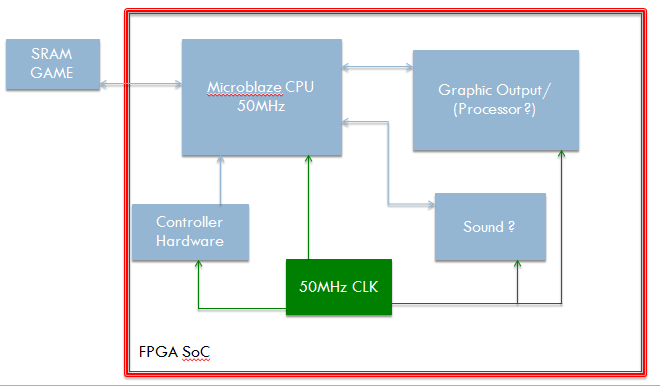


Figure 1: Our system

The first lab project was the NES Controller, which required VHDL code to generate signals and read button press input from the hardware. The next lab project was the first step in graphics, which involved hardcoding the video graphics array (VGA) in VHDL to display the eight possible colors on the screen. The third lab expands on this by creating VGAs for creating the tile-map and creating a VGA to display 64 pixels of sprites on the tiles for the character sprite and items. The fourth lab introduces using pointers with C Programming to control the FPGA, using two methods to control the speed of the LED-flashing pattern: a for-loop and the xtmrctr timer.

For the fifth lab, the previous four all contributed to its creation. The first lab provided the foundation for reading from the buttons of the NES Controller to the FPGA board. The second and third labs helped show how to create the sprites and tiles on the screen via VGA for our playable character, object, and background. Lastly, the fourth lab showed how to use the timer in C Programming so that we could paint the screen.

# Design Methodology

**Lab 1**

We created the first lab by first creating the VHDL code for generating signals and for reading the button input from the controller. The entity had the reset, clock, and NESdatIN as inputs and the buttenLED, NESlatch, and NESclk as outputs. This lab required the latch to have a 12us high signal and for the pulse to have a 12us per cycle. The latch will tell the controller to capture the button state and the pulse moves each button through the data output. With the provided UCF file, we were able to set the locations for the buttonLED vector on the FPGA, the clock, the NES clock, the NES data input, the NES latch, and the reset.

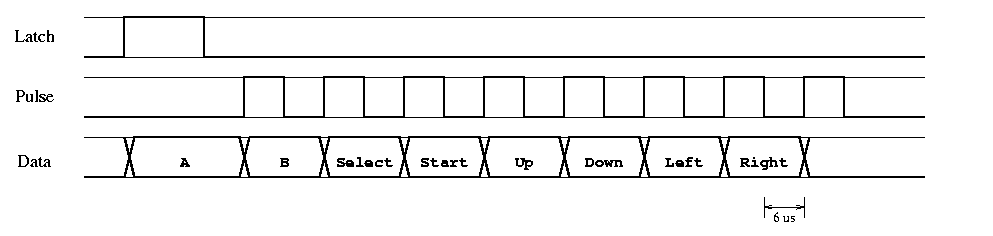


Figure 2: Timing required for Lab 1

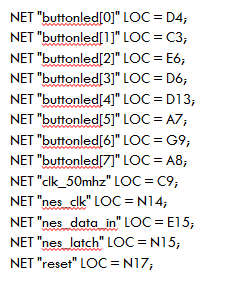


Figure 3: UCF file provided

**Lab 2**

For the second lab, we had to create a display file that outputs the x and y pixel coordinates hsync, vsync, and rgb. In our architecture, we defined all eight possible color combinations as 3-bit constants. The tile map is a 1200-bit array that had to be manually hard-coded to fill the entire array. With the vgatimehelper component, we could create a state machine to instantiate the VGA sync circuit. We then multiply the pixel y vector by 40 and then add it to pixel x to create our map index, which will get the pixel location. Lastly, the rgb buffer uses a state machine to paint the screen based on the tile map.



Figure 4: All of the eight available colors for the FPGA and their bit combinations.

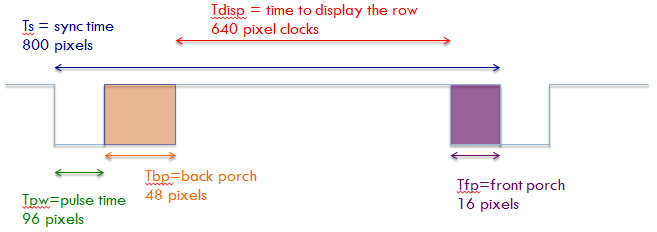


Figure 5: VGA pixels for a horizontal row

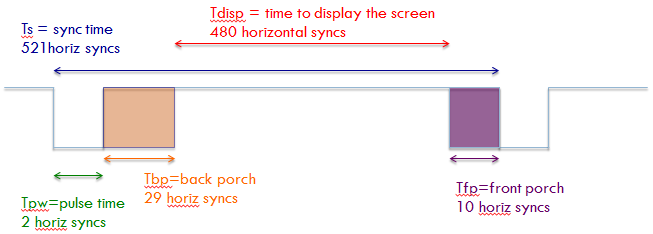


Figure 6: VGA pixels for a vertical column



**Lab 3**

Continuing from Lab 2, now we create sprites to appear on the screen. This requires making a sprite map where each sprite is 64 pixels and has an 8 x 8 arrangement. All sprites are stored in arrays similar to the tile map.

# Verification



Figure 7: For Lab 1, LED glowing when the start button is pressed

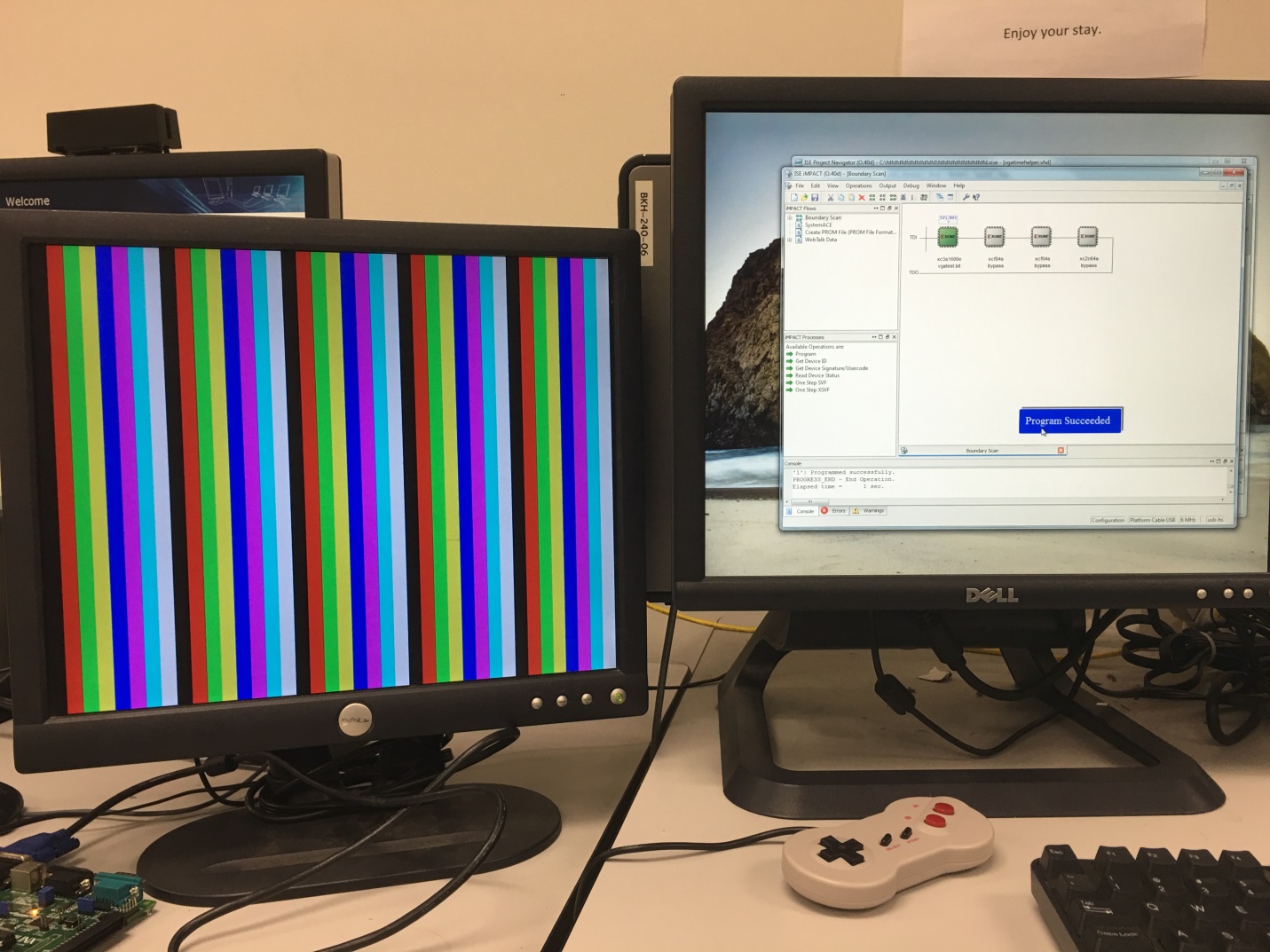


Figure 8: For Lab 2, all eight colors displaying on the monitor

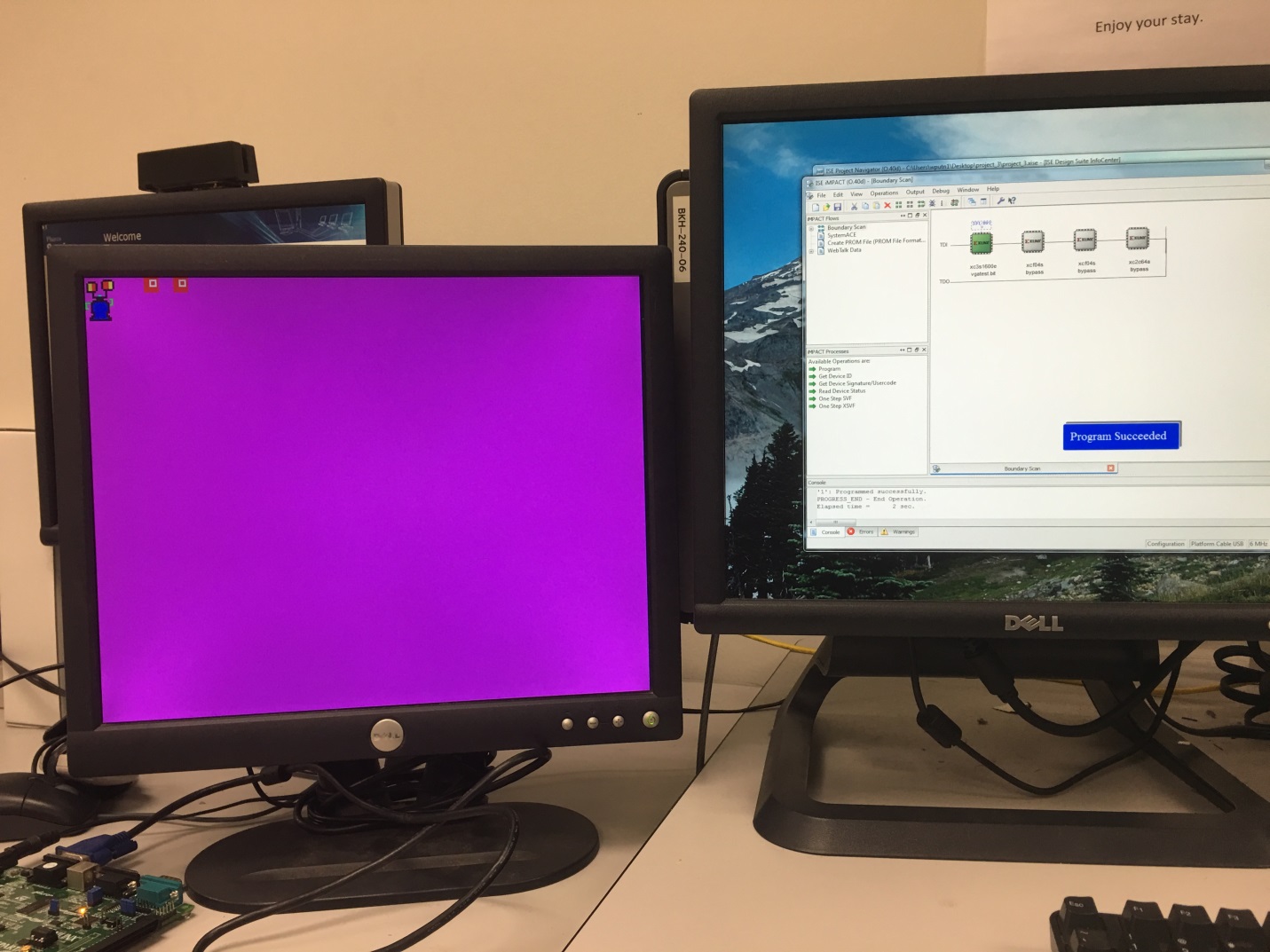


Figure 9: For Lab 3, playable character, object, and background displaying on the screen



Figure 10: For Lab 4, glowing LED pattern using for-loop



Figure 11: For Lab 4, displaying the LED-flashing pattern using the timer



Figure 12: For Lab 5, pushing the select button to make the object move to the right

# Conclusion

(Summarize project, how we could have improved it)