Digital Design with Field-Programmable Gate Arrays (FPGA)

Jayson Shiau

Faculty Mentor: Dr. Reza Hashemian

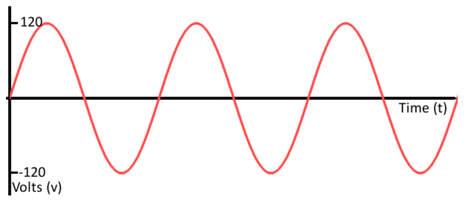
Department of Electrical Engineering, College of Engineering & Engineering Technology, Northern Illinois University

Northern Illinois University

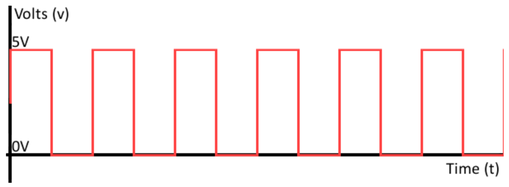
Introduction

Signals: Voltage changing over time that is sent and received to transfer data [1]. (Basis of technology)

Analog Signal: Voltage changing over time in an interval with infinite values [1]
Analog Electronics: Resistors, capacitors, diodes, transistors, amplifiers, etc [1].
Key Feature: Continuous signal (Below is an analog signal with infinite amount of voltage values being outputted)



Digital: Voltage changing over time in an interval with finite values that are stored as numbers [1].
Digital Electronics: Transistors, logic gates, microcontrollers, computing chips [1]
Key Feature: Finite number of values that determine signal (Below is a digital signal with two values 0V and 5V)

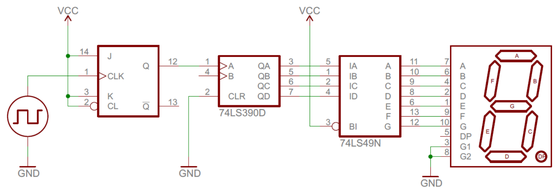


Background of Digital Design/FPGA

Digital Design involves designing digital systems and manipulating digital signals by writing software in Hardware Design Languages (HDLs). Two widely used HDLs today are Verilog and VHDL. HDLs are used to describe the behavior of logic circuits [2].

Previously, code that was written for traditional logic gate combinations known as Application Specific Integrated Circuits (ASICs) could not be changed after it was set. The advantage to using FPGAs is that designs can be changed late in the design cycle including after the product has been manufactured [3].

Most technology today uses digital systems, some with FPGAs that were designed by digital designers. Products include watches, computers, microwaves, refrigerators, televisions, etc.

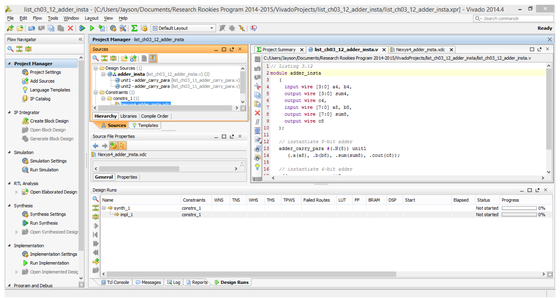


Research Objective and Methods

Objectives:
- To learn about Digital Design methodology
- To learn about the Verilog HDL (similar to C)
- To learn about the Xilinx Vivado Wepack Design Suite IDE
- To implement digital designs onto a Nexys™4 Artix-7 FPGA Board

Materials:
- Nexys™4 Artix-7 FPGA Board with a USB cable

- Xilinx Vivado Design Suite Wepback IDE incorporated with Verilog HDL to be used on a computer



Xilinx Design Process and Methodology:

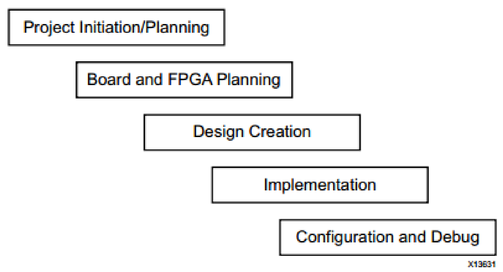


Figure 1-2: **Steps in Design Process**

1. Project Initiation/Planning – Defining the problem/task and setting out a plan to solve it using digital design methods
2. Board and FPGA Planning – Formatting the solution to fit the digital board and FPGA specifications
3. Design Creation – Writing the Verilog HDL code to describe the solution
4. Implementation – Loading the code onto the board
5. Configuration and Debug – Make any necessary changes after testing and troubleshoot before finishing.

Research Methods Continued…

Research Process:
- Lots of reading from "FPGA Prototyping By Verilog Examples : Xilinx Spartan-3 Version", a book by Chu, Pong P. that helps with providing lots of learn by example type scenarios that can be used in hands-on experiments

- Writing Verilog Syntax

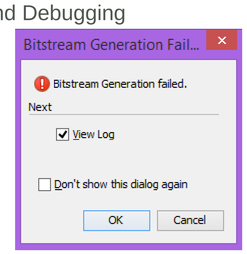
Project Summary | list_ch03_12_adder_insta.v

C:/Users/Jayson/Documents/Research Rookies Program 2014-2015/Vivado

```
1  // Listing 3.12
2  module adder_insta
3    (
4      input wire [3:0] a4, b4,
5      output wire [3:0] sum4,
6      output wire c4,
7      input wire [7:0] a8, b8,
8      output wire [7:0] sum8,
9      output wire c8
10   );
11
12   // instantiate 8-bit adder
13   adder_carry_para #(.N(8)) unit1
14       (.a(a8), .b(b8), .sum(sum8), .cout(c8));
15
16   // instantiate 4-bit adder
17   adder_carry_para unit2
18       (.a(a4), .b(b4), .sum(sum4), .cout(c4));
19
20 endmodule
```

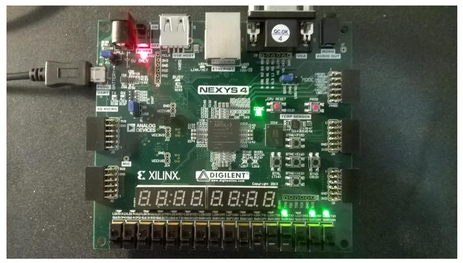
- Synthesis/Implementation (prepare code and load onto the board)

- Testing and Debugging



Results

This research project helped me to learn about the digital design process and how to create designs using the Verilog HDL and Xilinx Vivado Design Suite Webpack IDE. I was also able to learn how to implement code onto the Nexys™4 Artix-7 FPGA Board. It is exciting to know that the knowledge I gained will be essential for application in future technologies and research.



Discussion

Digital Design has come a long way from its beginnings and is still continuing to develop as our technology advances. By increasing our knowledge in this area, we can continue to make improvements on new innovations that come out and increase development efficiency due to the FPGA's feature of modifying a product even after it has been completed.

Conclusion and Directions

This project was a very fun and rewarding experience for me. It was definitely very slow at first because of the large amounts of reading and individual work that needed to be completed. However, Digital Design does have a very applicable aspect in the real-world and almost all technology depends on it. Little bits of signals can have huge impacts in data transfer and advancing our current technology to areas we would have never imagined.

Moving ahead, I intend to apply the knowledge I have gained in continuation of this project for applications in vision technology. This will require further research into allocation for random access memory (RAM), vision scoping, and image processing.

References:

[1] Learn.sparkfun.com, 'Analog vs. Digital – learn.sparkfun.com', 2015. [Online]. Available: https://learn.sparkfun.com/tutorials/analog-vs-digital. [Accessed: 30- Mar- 2015].

[2]R. Haskell and D. Hanna, Introduction to digital design using digilent FPGA boards. Rochester Hills, MI: LBE Books, LLC, 2009.

[3] Xilinx.com, 'What is a FPGA?', 2015. [Online]. Available: http://www.xilinx.com/fpga/. [Accessed: 30- Mar- 2015].

[4] M. Mano, Digital design. Upper Saddle River, NJ: Prentice-Hall, 2002.

[5] P. Chu, FPGA Prototyping Using Verilog Examples. Hoboken: John Wiley & Sons, 2008.

Acknowledgments

Research Rookies Program

McKearn Fellows Program

Dr. Reza Hashemian

NIU Department of Electrical Engineering