The Calculator

Performs Simple Operations: Addition, Subtraction, Multiplication, and Division

List of Authors (Kevin Bobernick, Dino Reed, Stephanie Rider, Hang Zhang)
Electrical and Computer Engineering Department
School of Engineering and Computer Science
Oakland University, Rochester, MI
e-mails: dlreed@oakland.edu, hzhang234@oakland.edu, sjrider2@oakland.edu, kmbobernick@oakland.edu

***Abstract*— This project envelops many useful techniques, some of which we learned in class, others that we discovered on our own. The scope of this project is quite technical involving digital logic that we learned throughout class as well as in our own research. We plan to create a fully functioning simple calculator using the Nexys4-DDR board with VHDL coding. These are the obvious tasks and techniques that are surrounding the project; what is often overlooked is the struggles of working with a group. This project also represents the teamwork as well as individual work that is a prominent aspect of the real engineering environment. Throughout the project we overcame the difficulties that faced us and were able to create a functioning simple calculator with two 4-bit inputs and one 4-bit output.**

I. INTRODUCTION

The scope of this project is to make a simple calculator using the Nexys4-DDR board and VHDL programming. This report will explain the process that we took creating a working calculator out of the aforementioned components and the obstacles that we faced in doing so.

Creating this calculator truly tested our knowledge on VHDL coding as well as the components that we used. We chose the calculator because it uses many relevant topics that we learned in class, the most obvious being the components that we previously designed in class. Even though a large portion of this was taught in class, we still had to research how to perform other operations for our calculator. Our project has an obvious application, which is as a calculator. Calculators are used by most people in their daily lives, especially those involved in this class, making it an invaluable piece of equipment.

Completing this project took many attempts of creating the calculator. We made each individual function and tested each one on the board before adding each of them to a top file to work simultaneously.

II. METHODOLOGY

A. Design

The design of our project was fairly simple: we utilized the 7-segment display incorporated on the board to display our output value. The inputs were binary values that used SW(0-7) on the board to determine their value. These were also represented by the LEDs above the switches to clearly represent the values of the two 4-bit inputs. Switches were also used to select which function the calculator was to perform. We used SW(12-15) to select addition, subtraction, multiplication, and division respectively.

B. Functions

The task of the function inputs was originally planned to be a keyboard. After researching the requirements to use a keyboard as an input, it was decided to use switches as our inputs, especially with our time constraint. There were 4 switches used as inputs to the calculator. Each switch was used as a binary input of a 0 or a 1. If the first switch was flipped up, the input would be a 0001, which would select addition. If the second switch was selected, the input would be 0010, selecting subtraction. The next switch would send an input of 0100, selecting multiplication. The last switch would send 1000, selecting division. All other values were considered null. This system was chosen to simplify the selection process to individual switches for ease of use for the calculator.

C. Arithmetic Operations

The next circuit component is the Arithmetic Logic Unit. This unit is the block that does the actual computation of results. Most of the code from this section was obtained through the lab done in this class. The Arithmetic Logic Unit (ALU) accepts as input three values. Two 4-bit binary values (DataA and DataB) are accepted as the operands to use for computation, and a 4-bit binary operator signal is used to select which operation should be performed. The ALU performs the computation and returns a 4 bit number. This is the result signal that is returned, which represents the result of the computation. For addition the two 4-bit binary signals are added and the resulting 4-bit binary result value is returned. If the resulting value is greater than 4 bits, the extra bits are removed as this is an unsigned addition. Similarly for subtraction, the two 4-bit binary signals (DataA and DataB) are accepted and the operation is performed as an unsigned subtraction. For multiplication, the two 4-bit inputs must be small numbers such that the product will be less than F. Finally for division, the ALU accepts the two 4-bit binary operands and performs the division which results in a 4-bit binary result signal.

D. Output

The final step in the digital calculator system is to display the output of the operation. In the original design, the output was designed to be output on a VGA display monitor. In working to get coding working to display the result on the VGA monitor, it was realized that the coding to get this work would have potentially taken several weeks to make it work. Since we did not have that much time to get a display that advanced to work, it was decided to display the results from hexadecimal. The serializer code given in class is used to display the result of the arithmetic calculation. This component displays the value of the 4-bit binary result signal on a 7-Segment display.

Along with the 7-segment display, the leds were utilized to display the binary input to the calculator. This takes out the factor of switches working improperly and making sure the

E. Teamwork

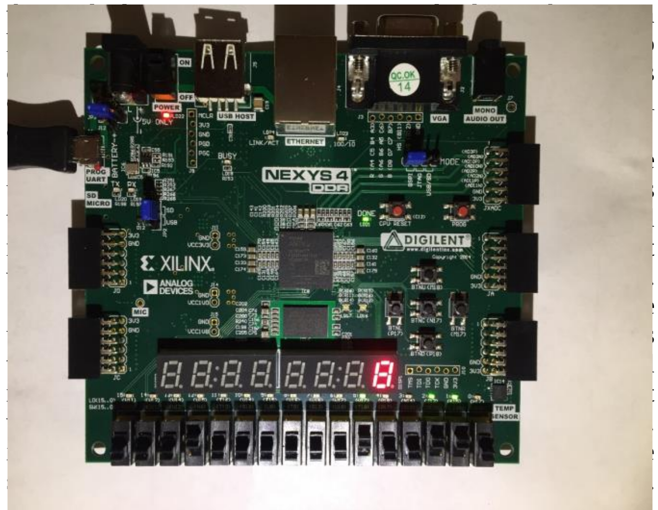
Working as a team always creates issues. Our group all had similar mindsets and project goals in mind; however, one of our greatest barriers was that of schedules. Between work and classes, we had difficulty finding time to meet together as a group. When we were able to meet it was more often a partial meeting and someone would call in. We were all more than willing to put the work in on our own time and gather together to review and help each other understand what we all learned. At this stage, we are still researching different options and gathering resources to build a better calculator. I would say that thus far, we have worked together very effectively showing strength both as individuals as well as with our group collaboration.

III. Experimental Setup

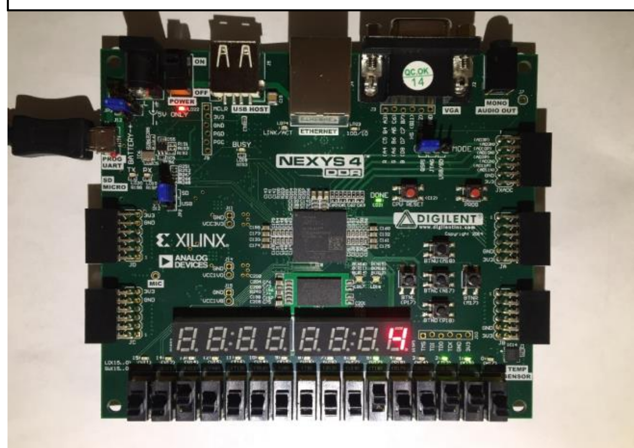
The setup that was used for this project involved VHDL code and the Nexys4-DDR board. The VHDL code was written on a computer and uploaded to the Nexys4-DDR board which used the switches on the board to implement the adder, subtractor, multiplier and divider. This was implemented by setting up switch 12-15 as the functions and used two sets of signal switches, Signal A and B. Signal A was set to switches 0-3 and corresponded to the input of the base number that was added, subtracted, multiplied or divided while switches 4-7were set to represent the number that was being added, subtracted, multiplied or divided into the first. A seven segment display was also used to show the inputted number as well as the results after the function was carried out. The expected results are a calculator that can do simple operations up to 4 bits using switches to as the input values and function values.

IV. Results

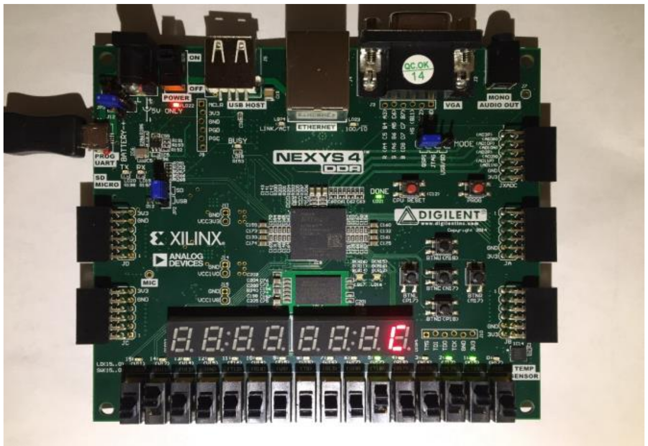
The pictures below show how the calculator works:



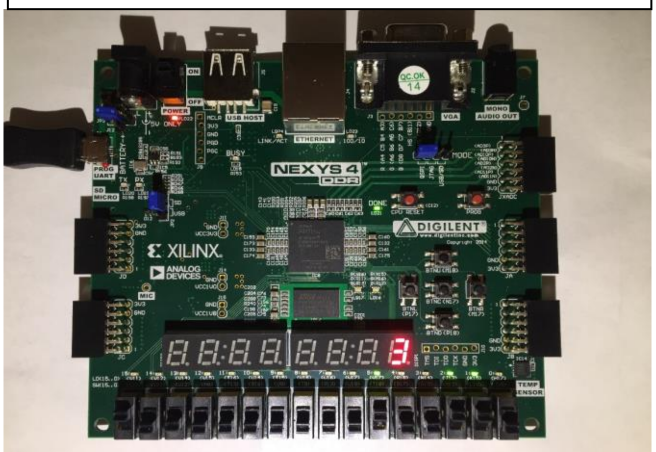
DataA = 6 by SW(0-3) , DataB = 2 by SW(4-7), LEDs indicate the switch is on, addition mode enabled by SW(12). Provides the output on the 7-segment display which is 6+2=8.



DataA = 6 by SW(0-3) , DataB = 2 by SW(4-7), LEDs indicate the switch is on, subtraction mode enabled by SW(13). Provides the output on the 7-segment display which is 6-2=4.



DataA = 6 by SW(0-3) , DataB = 2 by SW(4-7), LEDs indicate the switch is on, multiplication mode enabled by SW(14). Provides the output on the 7-segment display which is 6*2=C or 12.



DataA = 6 by SW(0-3) , DataB = 2 by SW(4-7), LEDs indicate the switch is on, division mode enabled by SW(15). Provides the output on the 7-segment display which is 6/2=3.

Conclusions

This project was a nice dive deeper into how adders, subtractors, multipliers, and dividers work. It took time to be able to put everything together and even finding simple code online as a reference proved to only help to a certain extent. The calculator was tricky but as a whole, our group understanding of how a mux and 7-segment display works is vastly improved. Some issues that remain to be solved would be that our board is limited to F, or 15. It is unable to show any numbers correctly that are higher than the value of 15. Improvements that can be made to our project would be extending the number of bits that both the inputs and output can show, use a keyboard or number pad as the input, use a VGA display to show the ouput results, allow for the calculator to show signed binary inputs, and add more functions to the calculator such as square roots or exponentials.

References

[1] "Thread: DE2-115 (Help w/ LED & SWITCH program)." Altera Forums RSS, Intel, 6 Mar. 2015, 14:58 www.alteraforum.com/forum/showthread.php?t=47925

[2] Llamocca, Daniel. "VHDL Coding for FPGAs." VHDL Coding for FPGAs, Oakland University, www.secs.oakland.edu/~llamocca/VHDLforFPGAs.html