

**Digital Design Lab  
ECN 315**

**Lab/Project 5  
Multiplier**

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April 16 2016**

## **Abstract**

### **[4 marks]**

A short overview of the Lab/Project (100-200 words) Include the following:

- The purpose of this lab was to implement a 4 bit adder, subtractor and multiplier using all of the components we created during our previous lab. We learned how to convert an 8 bit input into a two digit decimal output display. This was useful to display larger numbers.
- This project introduced us to the creation of a fully functional calculator. We also learned how registers work and used them to store data for our calculations.
- The end result of this lab was a fully functional calculator that was implemented for the DE2 board.
- Overall, this lab taught us how to connect and adapt previously designed components into one coherent circuit. Building a calculator allows one to learn a variety of circuit design structures.

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## Overview

A four bit multiplier is a useful tool to have in computers. The APU of a computer wouldn't be able to function if it weren't for binary arithmetic operations, one of which is unsigned multiplication. We designed our using the shift algorithm approach. Multiplication is an important subject in computing because it represents the fundamental arithmetic operations a computer can calculate. Unsigned operations greatly benefit a computer's ability to handle modern problems.

## Objectives

Design a 4 Bit Multiplier using the add and shift algorithm.

## Equipment

Description
A computer running Windows 7
Quartus II software
DE2 Board

## Description

In order to create our final circuit, we first had to implement various components that together would work together to multiply two four bit numbers. Since our logic relied on the add and shift algorithm, we first had to implement a four state counter similar to the one implemented in lab1. We then created a BCD display to properly display our output in decimal to two hex displays. Once that was implemented, we created an 8-bit register to store our intermediate multiplicand values. When creating the multiplier, we decided to use a 4:1 Mux to optimize our algorithm (since we don't need to add zeros to our number). We finished implementing our calculator by connecting all of the components together.

## Specifications

This lab required us to use Quartus II schematic blocks from previous labs.

## 3-bit Up Counter

The purpose of having the 3-bit Up Counters, to convert an 8 bit binary input into a two four bit decimal representation of the output. Making it easier to display. Furthermore, we also implemented a four state counter that helped us implement the add and shift algorithm for our multiplier. This counter allowed us

to iterate through the shifts of the number.

## Design Synthesis Or VHDL Code

K-maps, truth tables, Boolean expressions, and a *step by step explanation* of the logic behind the design.

Step 1.

Implement the 3 bit counter.

Step 2.

Create the BCD display.

Step 3.

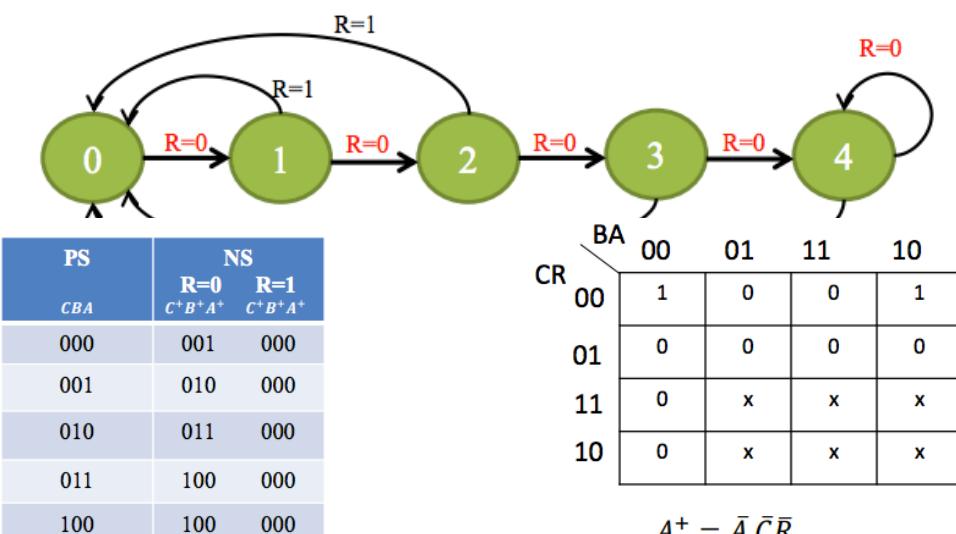
Design the 8 bit register

Step4.

Create the multiplier by using the 4-bit adder, 4:1 Mux and the 8-bit register.

Step5.

Connect the clock input and reset to the 3-bit counter and the multiplier, as well as all of the inputs and outputs.



CR BA	BA			
	00	01	11	10
00	0	1	0	1
01	0	0	0	0
11	0	x	x	x
10	0	x	x	x

$$B^+ = A'BR' + AB'R'$$

CR BA	BA			
	00	01	11	10
00	0	0	1	0
01	0	0	0	0
11	0	x	x	x
10	1	x	x	x

$$C^+ = ABR' + CR'$$

Figure 2. Truth Table and K-Maps

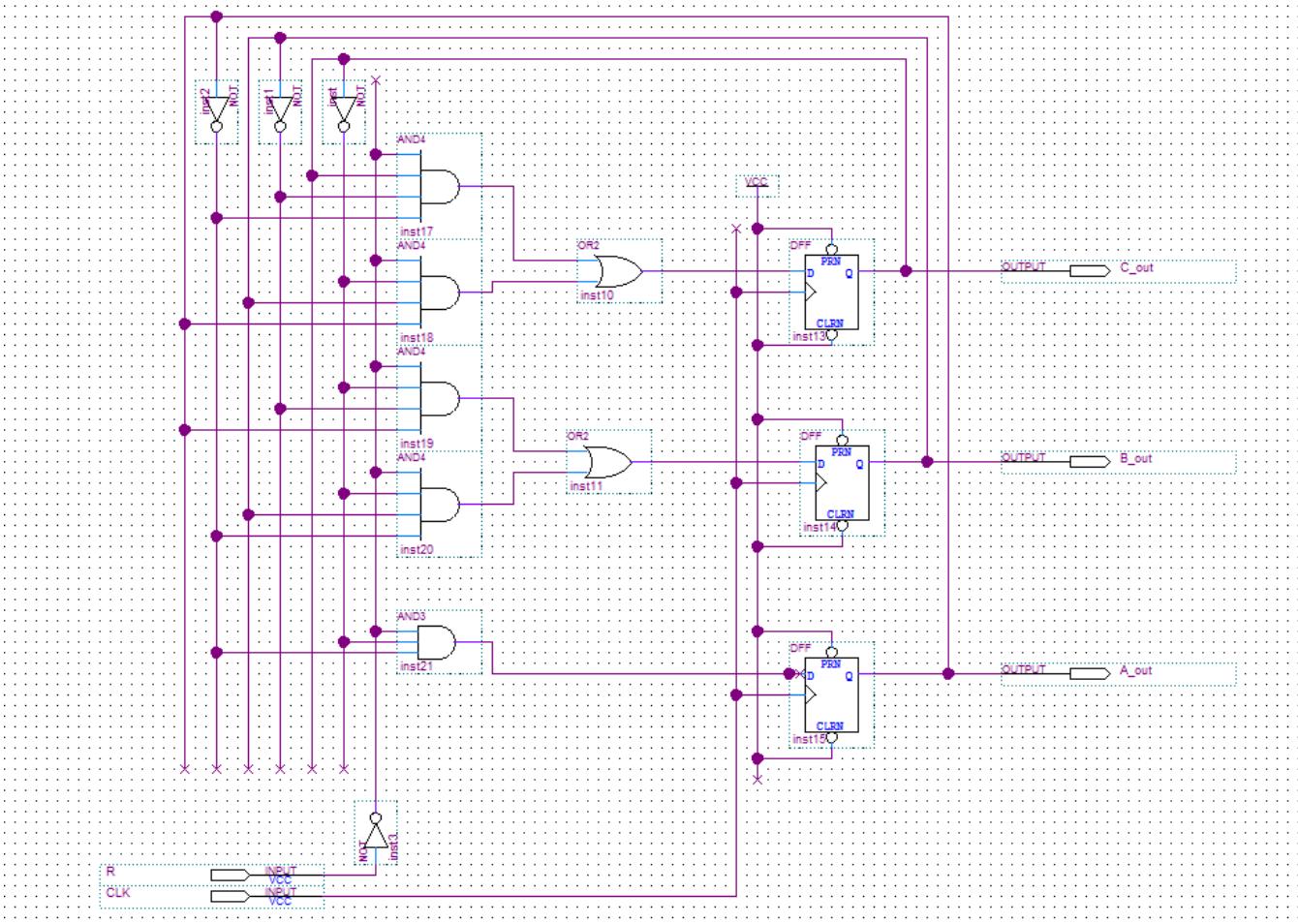


Figure 3. Counter Block Diagram

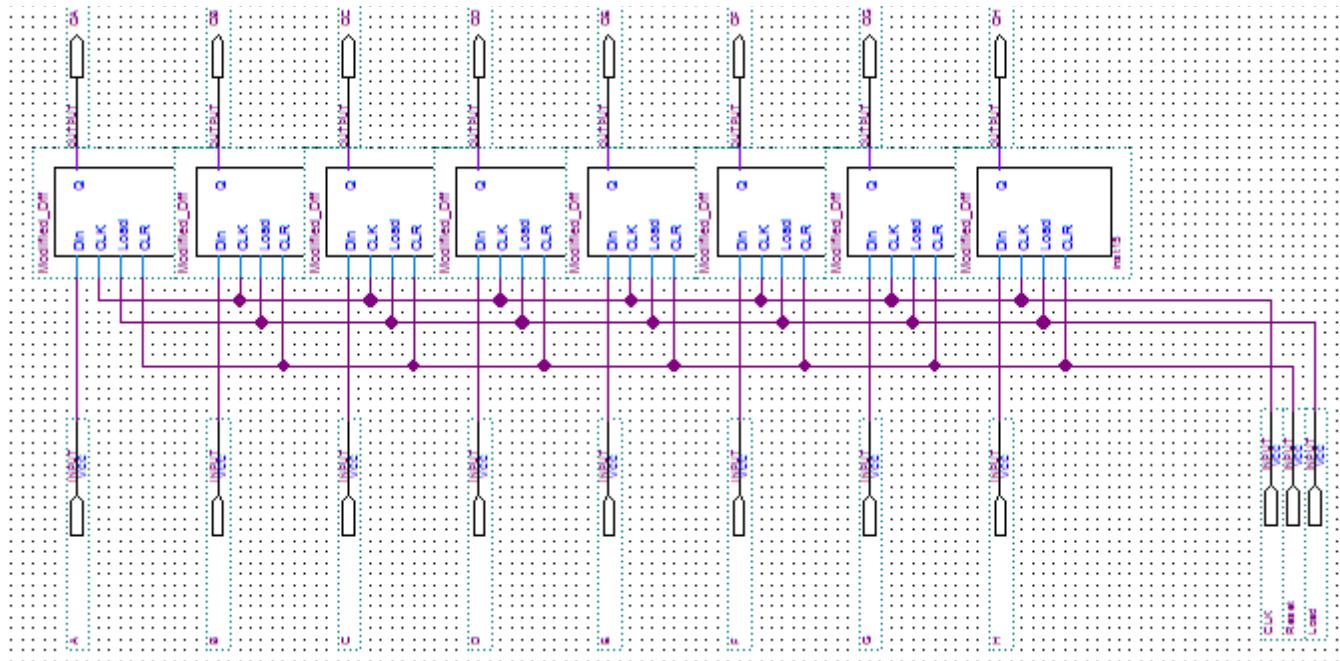


Figure 4. 8-bit register

A	B	C	D	QA	QD	QC	QD	A' = D'C'A + DA' + CBA'
0	0	0	0	0	0	0	0	
1	0	0	0	1	0	0	1	
2	0	0	1	0	0	0	1	
3	0	0	1	1	0	0	1	
4	0	1	0	0	0	1	0	
5	0	1	0	1	1	0	0	
6	0	1	1	0	1	0	1	
7	0	1	1	1	1	0	0	
8	1	0	0	0	1	0	1	
9	1	0	0	1	1	1	0	

CDIAB	00	01	11	10	CDIAB	00	01	11	10
00	0	0	x	1	00	0	1	x	0
01	0	1	x	1	01	0	0	x	1
11	0	1	x	x	11	0	0	x	x
10	0	1	x	x	10	0	0	x	x

QA =	BD + BC + AC'	QB =	BCD + AD	QC =	CDIAB	QD =	A'B'D + BCD' + AD'		
CDIAB	00	01	11	10	CDIAB	00	01	11	10
00	0	0	x	1	00	0	0	x	1
01	0	0	x	0	01	1	0	x	0
11	1	1	x	x	11	1	0	x	x
10	1	0	x	x	10	0	1	x	x

Figure 5. BCD Truth Table and K-Maps

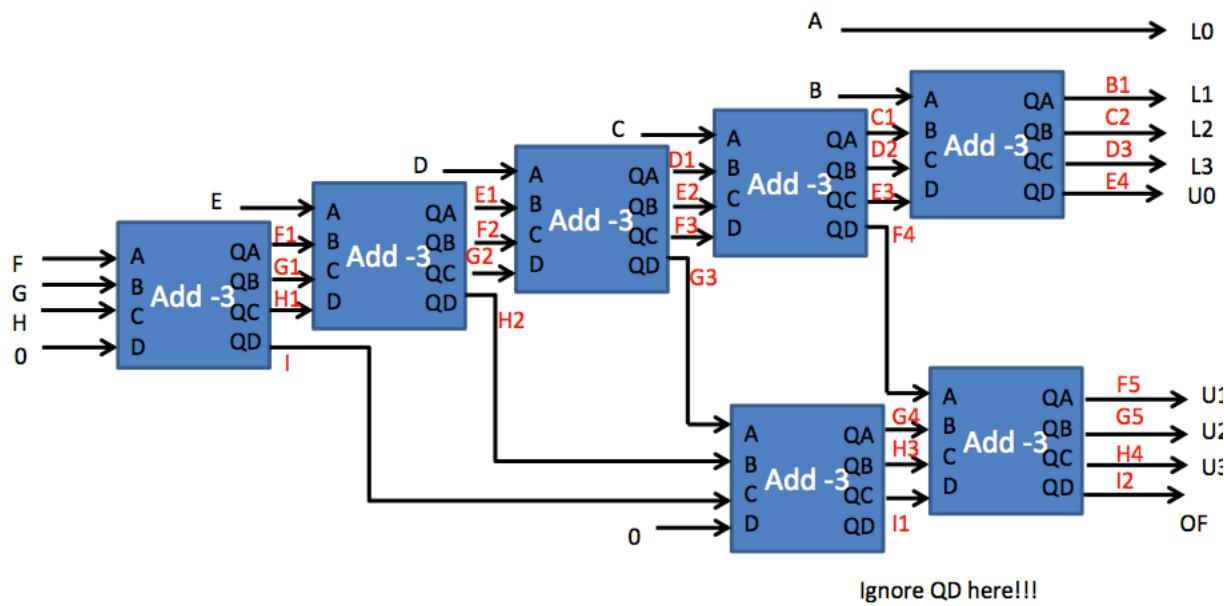


Figure 6. BCD Alg

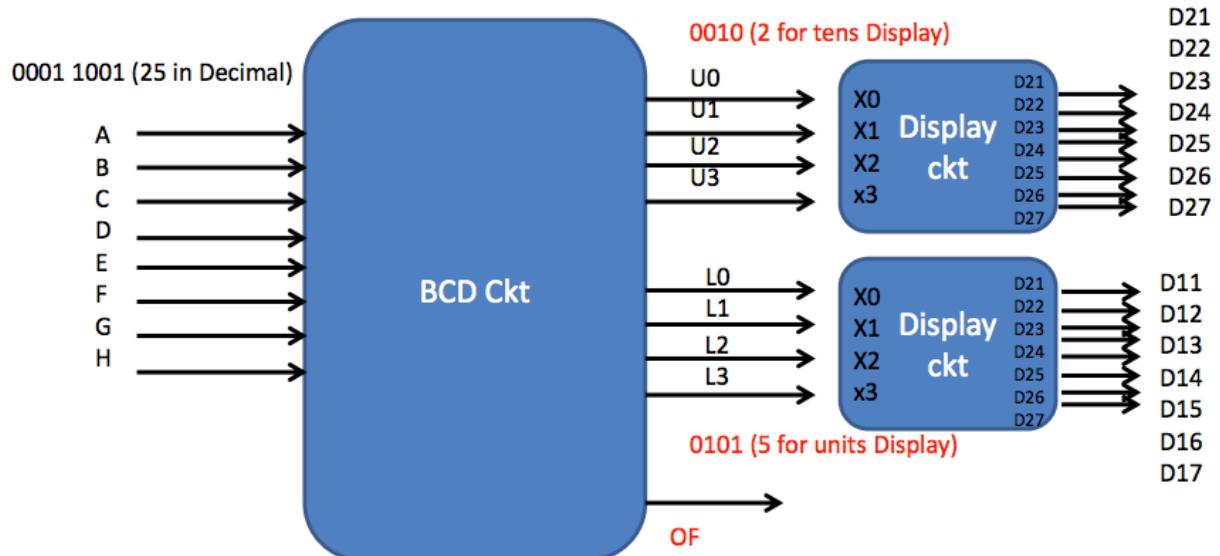


Figure 7. BCD Display

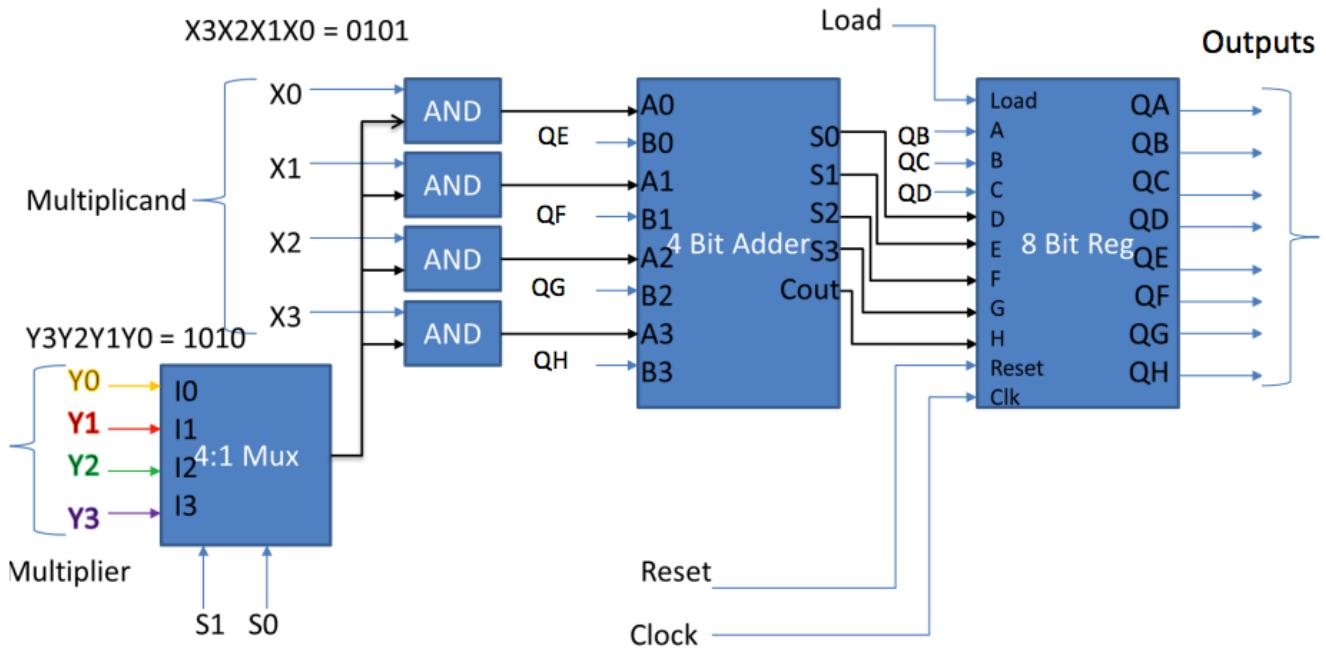


Figure 8. 4-bit Multiplier

## Complete Logic Diagram

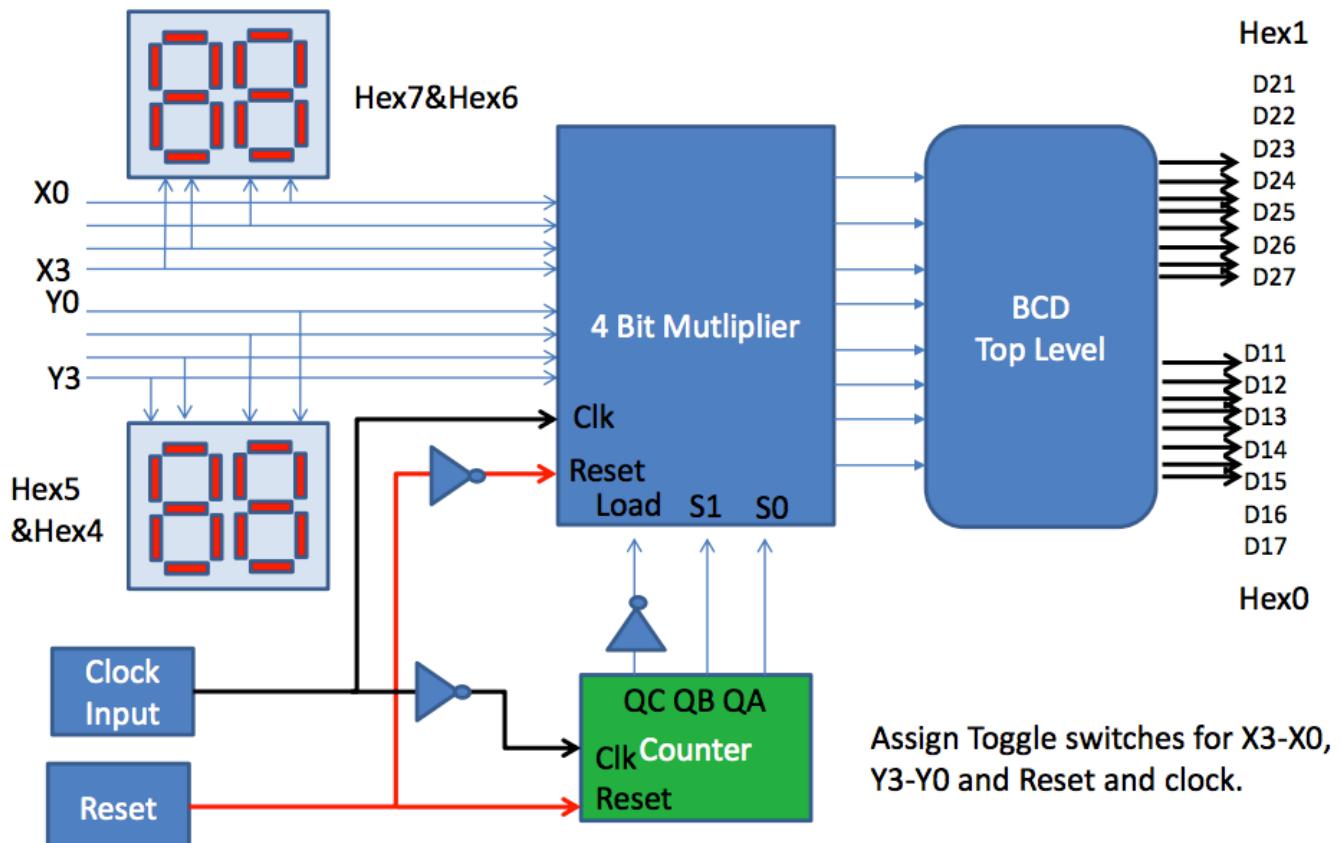


Figure 9. Complete Logic Diagram

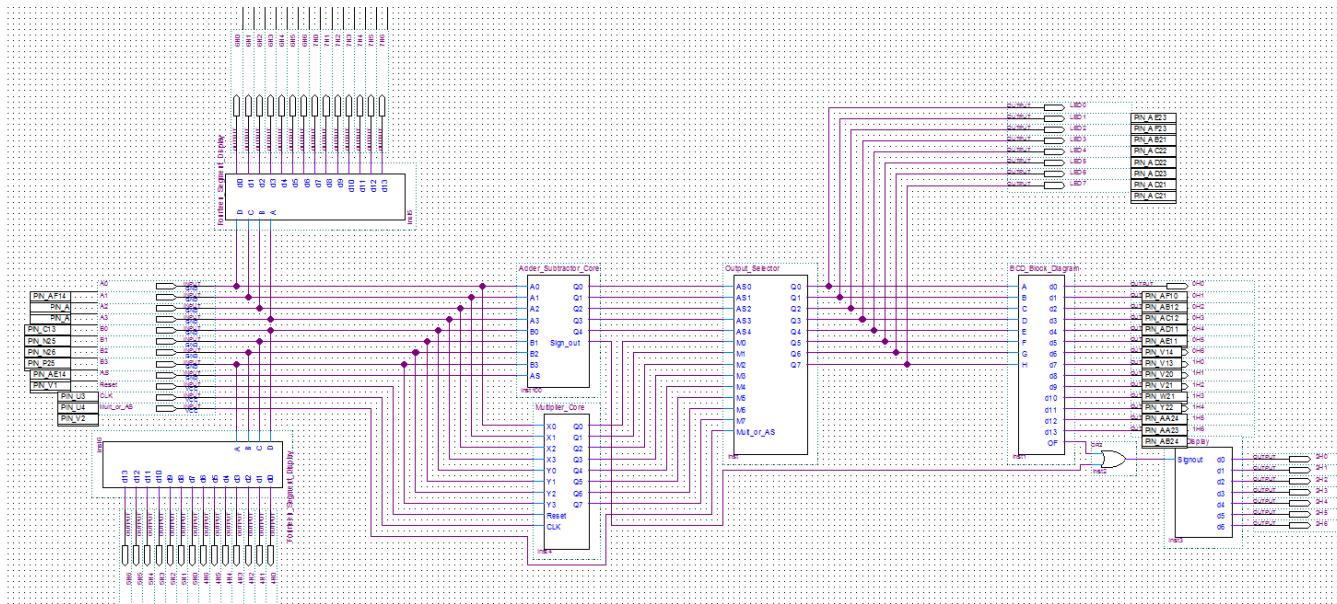


Figure 10. Complete Calculator Logic Diagram

## Results and Simulations

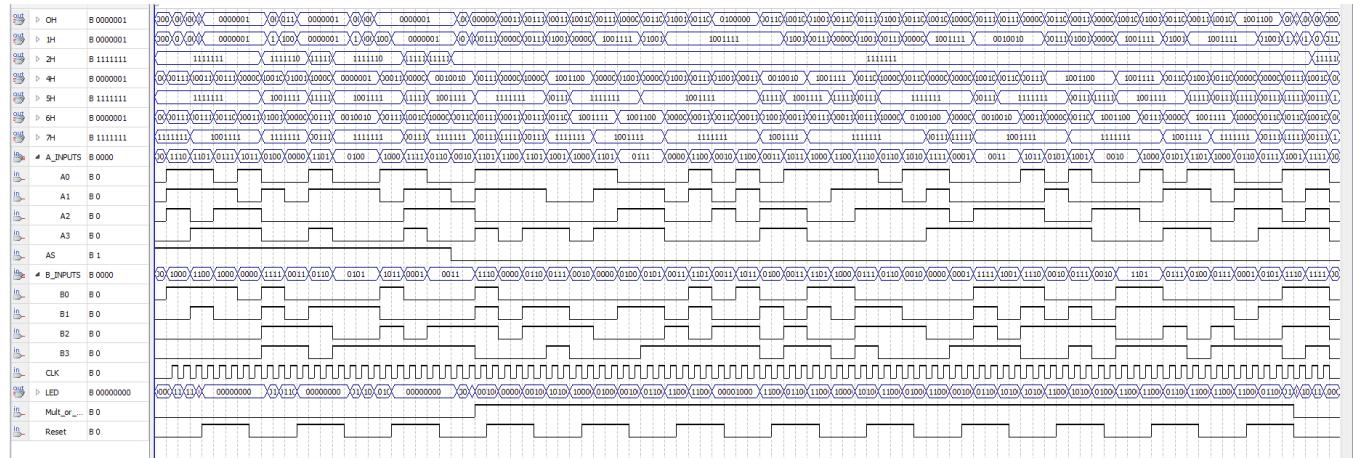
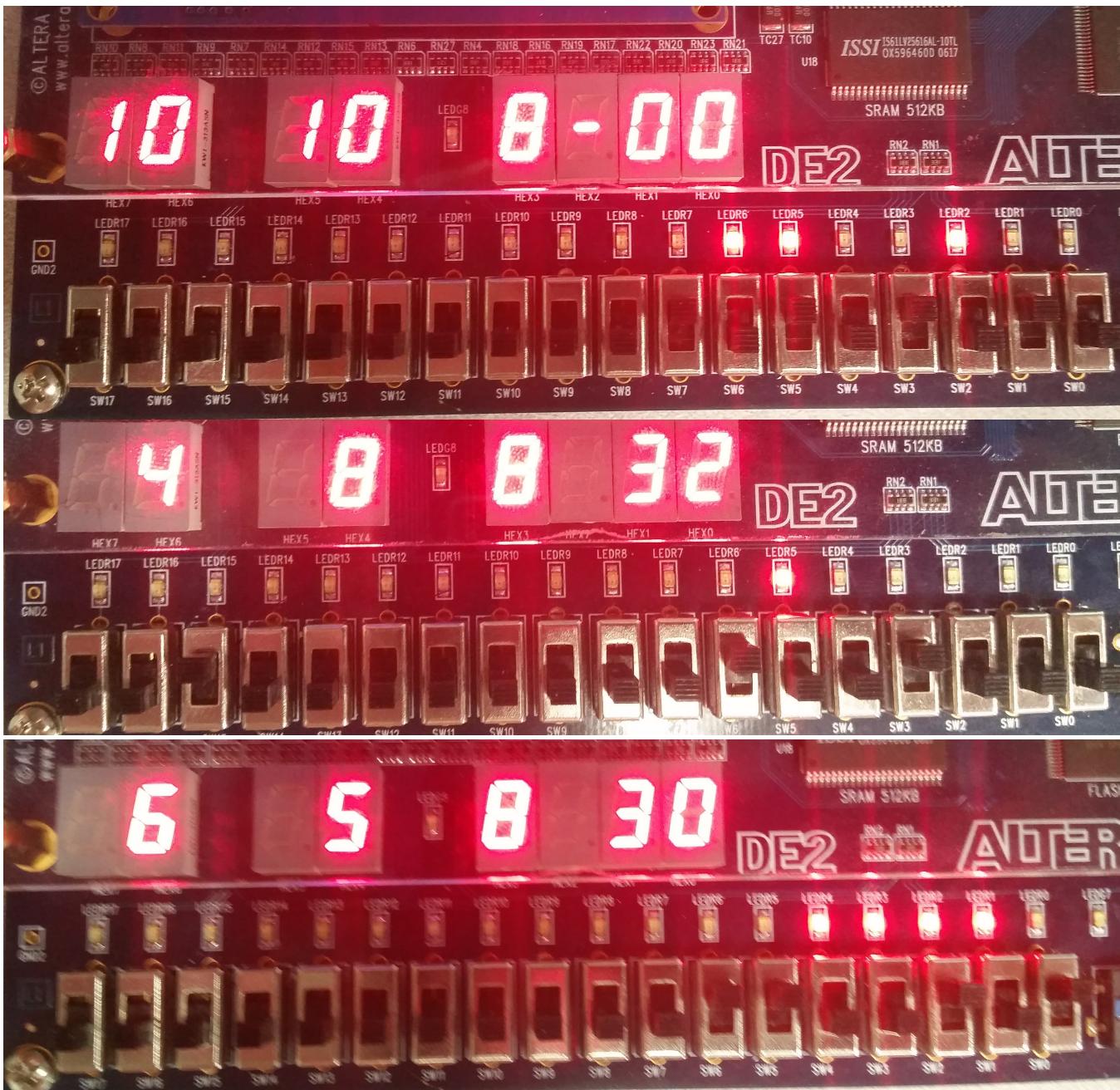


Figure 11.Final project simulation



## Conclusion

The conclusion should include the following:

- In order to create our four bit multiplier, we had to use the add and shift algorithm. In order for it to work, we had to implement a four stage counter, an 8-bit register, and a BCD display to convert the 8-bit output into a decimal representation of the numbers using two seven segment displays.
- The major problem we encountered during this lab was the reset of our registers. We never implemented it at the beginning so we had to go back and redesign it when building the calculator.

- c. Our calculator is limited by the numbers it can display. Theoretically, our counter could go up to 225 but it can only display up to 99.
- d. During this lab, we learned how to implement a BCD display and an 8-bit register. These are useful skills to have since they can always be used for future projects.

## **Works Cited**

[https://www.courses.miami.edu/bbcswebdav/pid-7493476-dt-content-rid-11077269\\_1/courses/ECE315-E1-05939-1-20171/Lab%20A%20UpCounter%26Register%26BCD.pdf](https://www.courses.miami.edu/bbcswebdav/pid-7493476-dt-content-rid-11077269_1/courses/ECE315-E1-05939-1-20171/Lab%20A%20UpCounter%26Register%26BCD.pdf)

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