EGCP 1010
Digital Logic Design (DLD)
Laboratory #4

Three (3) Digit Binary Coded Decimal (BCD) Adder

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on

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Objective:

The goal of this laboratory is to teach the student to learn to create a hierarchy for complex tasks. The student should also become more of an advanced user of CedarLogic and should understand BCD addition more fluently.

Procedure and Results:

Before entering the lab, we read the handout on BCD addition to become more familiar with it. We also found the K-Map for the equation OC, which is shown in Table 1.

OC(K,S3,S2,S1,S0) = $\sum$m(10,11,12,13,14,15) + K

Table 1: The Truth Table for OC

0	0	1	0
0	0	1	0
0	0	1	1
0	0	1	1

K is the carry Output Carry from the first adder.

We then designed the circuit shown in Figure 1, which is Figure 3-34 on the BCD handout.

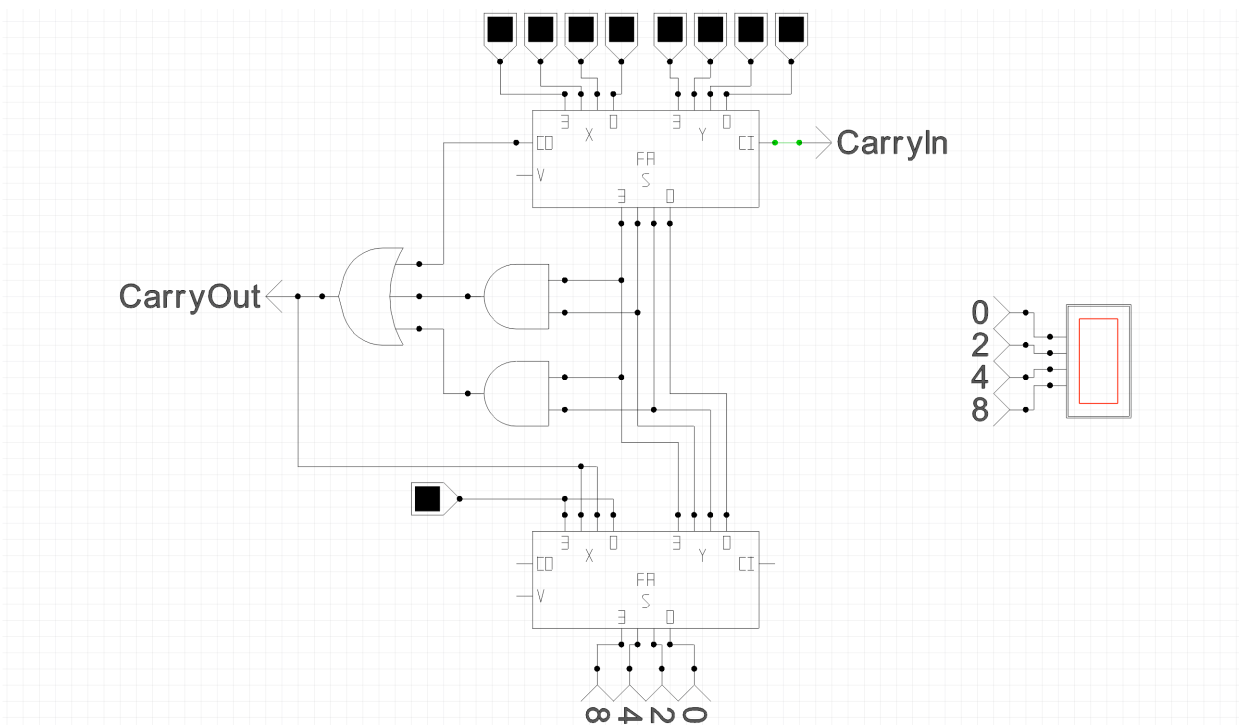

Figure 1: Figure 3-34 from the BCD Handout

In lab, we completed the circuit shown in Figure 2 in CedarLogic.

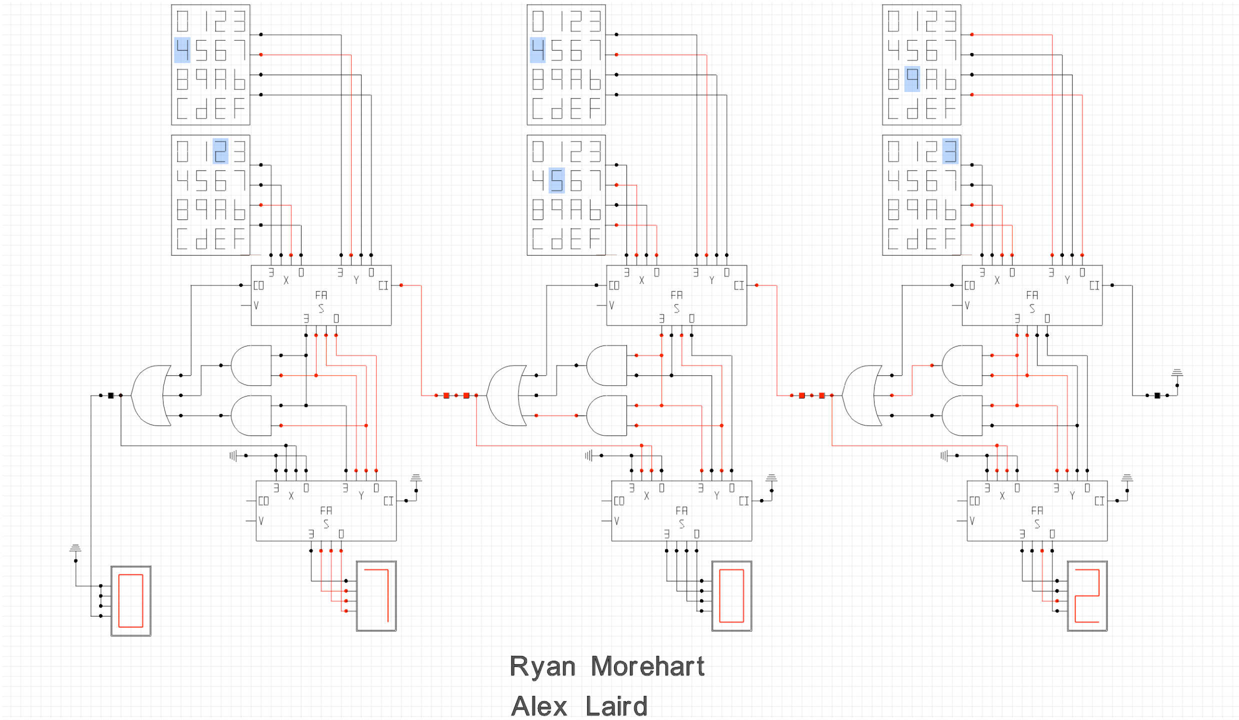

Figure 2: Three (3) Digit BCD Adder In CedarLogic

This is a three (3) digit BCD adder, which takes three one (1) digit adders and couples them together. Individually, each one (1) digit adder takes two one (1) digit numbers, converts them to BCD format (four binary digits), and does a simple binary addition on them. If the resulting answer is greater than nine (9), six (6) will be added to the final result, which will surpass the remaining six (6) digits in base sixteen (16) (A_{16}, B_{16}, C_{16}, D_{16}, E_{16}, F_{16}). A base ten (10) one (1) is then carried to the next digit position. An example is shown below.

$$\begin{array}{r} 0100 \\ \underline{+\ 1101} \\ 10001 \end{array}$$

Since this result is great than nine (9), we add six (6) to it.

$$\begin{array}{r} 10001 \\ \underline{+\ \ 0110} \\ 0001\ 0111 \end{array}$$

The answer is now in BCD format, and can easily be converted back to base ten (10) by simply grouping each four binary digits and converting them to base ten (10). The answer to this problem, 4 + 13 = 17.

If the resulting answer is not greater than nine (9), no carry is needed.

This will result in a one (1) decimal digit adder. Two easily make this into a three (3) digit decimal adder, simple copy and paste the circuitry. Connect the carry output to the carry in. Note that, due to the correction logic between the two four (4) binary bit adders in each one (1) digit adder, a carry bit is only set to one (1) if the the eights position AND the tens position, OR the eights position AND the fours position are both true, indicating the number is greater than nine (9). If this is not the case, the carry is set to zero (0), so nothing is carried to the next adder.

Note that there is one final digital output display. This is for the final carry bit. There will always be *one more* output than input. The output may not be used if the final addition is not greater than nine (9), but it must be available, just in case.

Conclusion and Suggestions:

This lab was my favorite so far, and was very insightful, especially in illustrating the sheer simplicity of binary logic and, especially, addition. It showed how easily multiple circuits can be tied together as well. It also illustrated the usefulness of hierarchy very well.

Questions:

I. Describe in detail how the one (1) digit BCD adder works. Your answer should include the BCD addition algorithm and how this circuit implements that algorithm. Include at least two example additions.

A BCD adder simply uses four (4) Full Adders, connected together, which we designed in a previous lab. Each Full Adder can add up to three binary digits. Each binary digit is added in a Full Adder, and the carry, if any, is passed onto the next Full Adder.

II. Many small calculators have eight (8) digits. Write a brief paragraph describing how easily your design could be extended to eight (8) BCD digits.

In the same way that two (2) more BCD connected were added, as explained in the Procedure and Results section, to the existing BCD adder, five more could be added above, connecting the carry in of each BCD adder to the carry output from the previous BCD adder.