Jeide, Matthew Date Period

aW5/6B: DE 2.3.4 Two's Complement Arithmetic

Introduction

The world's first all-transistor calculator was the IBM 608. The 608 was introduced in 1955 at a cost of $83,210. The calculator was the size of a large dresser! The 608 was capable of addition, subtraction, multiplication, and division—the same capabilities of a four-function calculator that you can buy today at a store for $2.99. Despite the tremendous decrease in size and price that has occurred over the last five decades, the underlying design principles for the two calculators are the same.

In this activity, you will implement an adder that combines two 2-bit numbers. This 2-bit adder design is a simplified version of the adder that is in a four-function calculator. You will implement both a small-scale integration (SSI) and medium-scale integration version of the 2-bit adder.

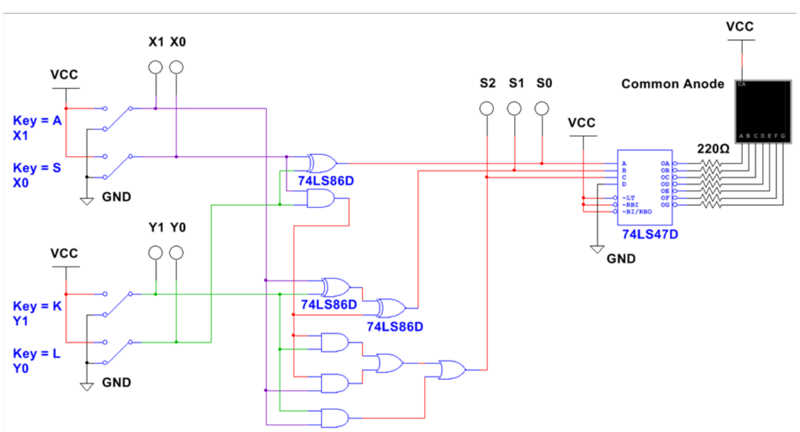
Equipment

Calculator (preferably one with a number base conversion feature)

Procedure

Presentation: Review XOR, XNOR, and Binary Adders.

Using the CDS, enter the 2-bit adder shown below. This adder is implemented with SSI logic (i.e., AND gates, OR gates, and XOR gates).



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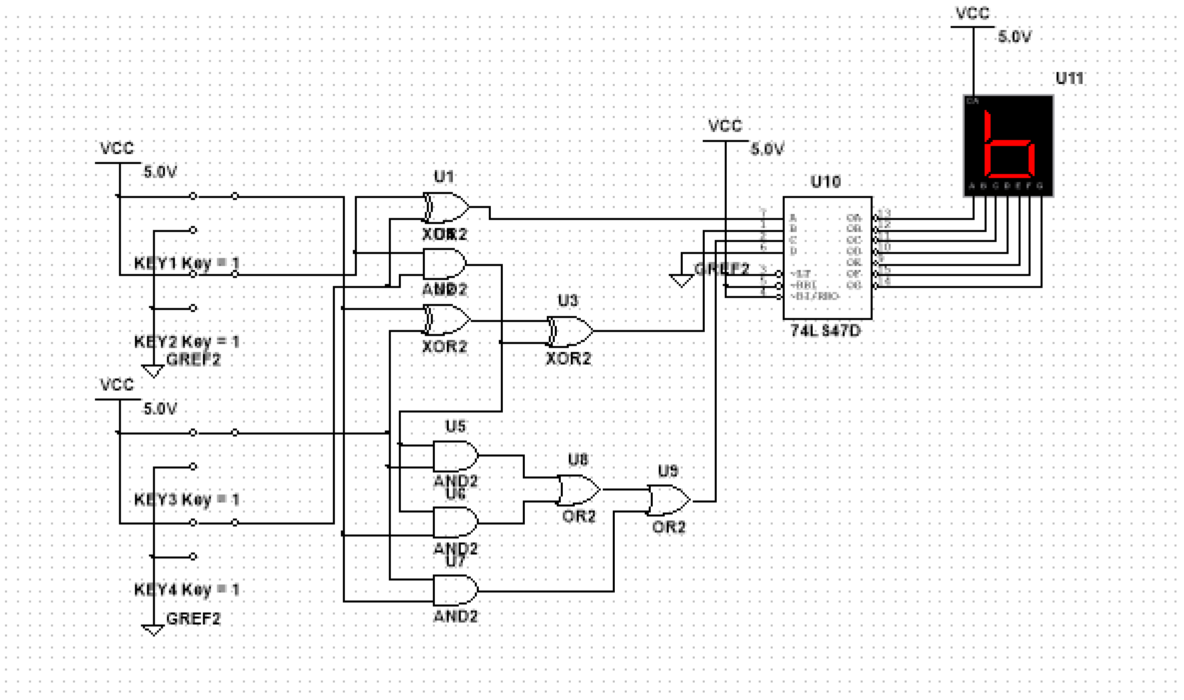
Insert a screenshot of the Multisim design



This circuit has two 2-bit inputs (X1, X0 and Y1, Y0) and three outputs (S2, S1, and S0). S2-S0 is the sum of adding together X1-X0 and Y1-Y0. Additionally, the outputs (S2-S0) are connected to a **common anode seven-segment display** through a 74LS47 display driver.

> **Note**: The wires are color-coded to help with readability; these colors do not need to be maintained in your drawing.

Verify that the circuit is working as expected by completing the truth table in your notebook

Inputs						Outputs			
X1	**X0**	**X**	**Y1**	**Y0**	**Y**	**S2**	**S1**	**S0**	**Display**
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	1	0	0	1	1
0	0	0	1	0	2	0	1	0	2

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0	0	0	1	1	3	0	1	1	3
0	1	1	0	0	0	0	0	1	1
0	1	1	0	1	1	0	1	0	2
0	1	1	1	0	2	0	1	1	3
0	1	1	1	1	3	1	0	0	4
1	0	2	0	0	0	0	1	0	2
1	0	2	0	1	1	0	1	1	3
1	0	2	1	0	2	1	0	0	4
1	0	2	1	1	3	1	0	1	5
1	1	3	0	0	0	0	1	1	3
1	1	3	0	1	1	1	0	0	4
1	1	3	1	0	2	1	0	1	5
1	1	3	1	1	3	1	1	1	6

2. Using the CDS, enter the 2-bit adder shown below. This adder is implemented with 74LS183 **MSI** full add gates.

> **Note:** The 74LS183 MSI is a medium-scale integrated (MSI) circuit. You will learn more about MSIs in the next unit.

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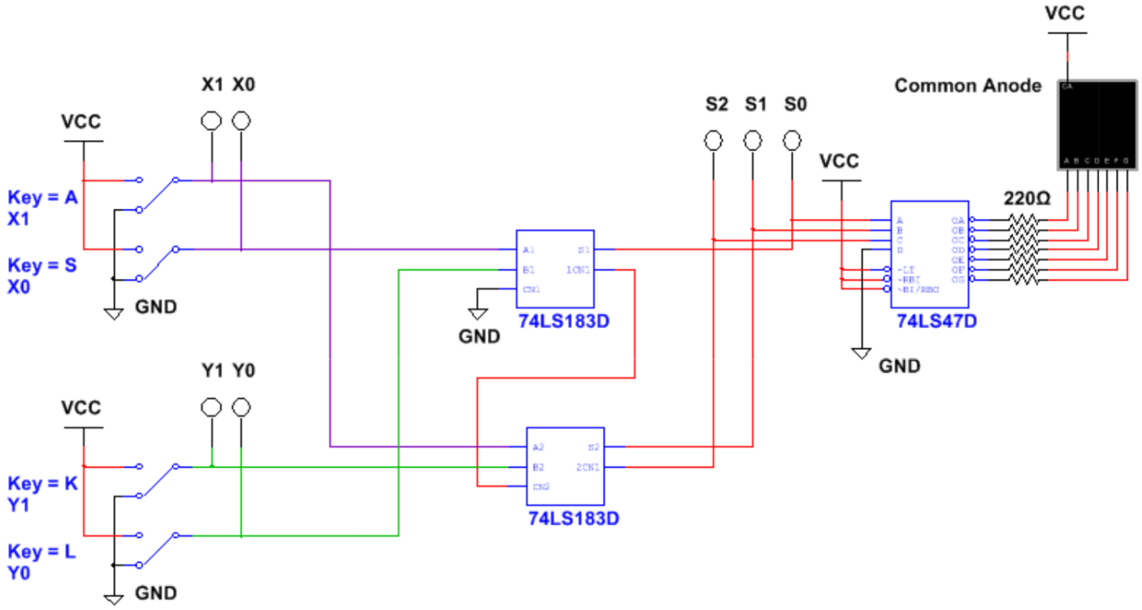
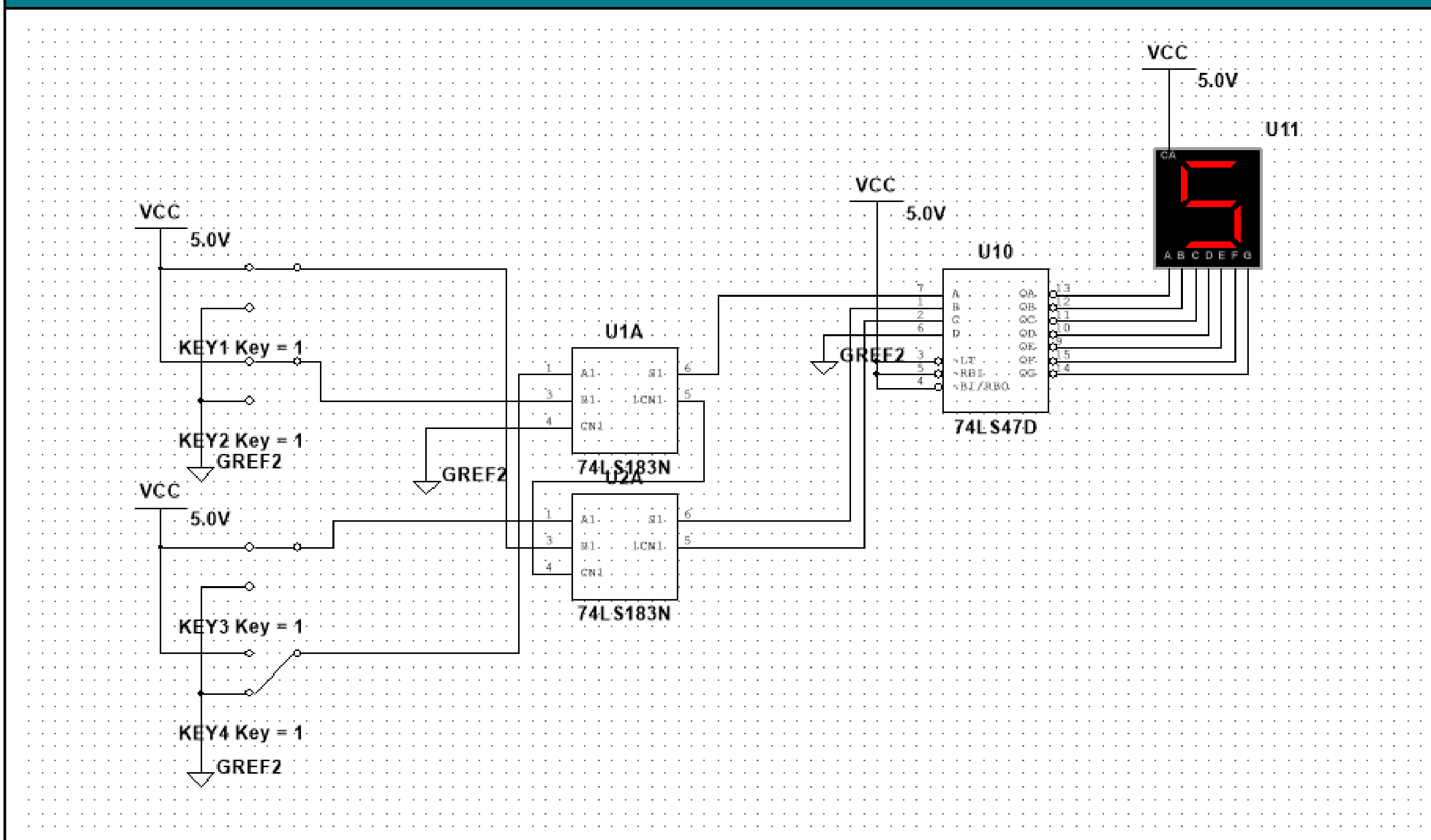


Insert a screenshot of the Multisim design



This circuit is functionally identical to the SSI implementation from step 1.

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Verify that the circuit is working as expected by completing the truth table in your notebook.

Inputs						Outputs			
X1	**X0**	**X**	**Y1**	**Y0**	**Y**	**S2**	**S1**	**S0**	**Display**
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	1	0	0	1	1
0	0	0	1	0	2	0	1	0	2
0	0	0	1	1	3	0	1	1	3
0	1	1	0	0	0	0	0	1	1
0	1	1	0	1	1	0	1	0	2
0	1	1	1	0	2	0	1	1	3
0	1	1	1	1	3	1	0	0	4
1	0	2	0	0	0	0	1	0	2
1	0	2	0	1	1	0	1	1	3
1	0	2	1	0	2	1	0	0	4
1	0	2	1	1	3	1	0	1	5
1	1	3	0	0	0	0	1	1	3
1	1	3	0	1	1	1	0	0	4
1	1	3	1	0	2	1	0	1	5
1	1	3	1	1	3	1	1	1	6

3. In the space provided below attach this completed worksheet to your E-Portfolio.

Insert your work on your E-Portfolio. Attach your E-Portfolio link here. Make sure to include a video of the XOR and the XNOR adding the values.
https://sites.google.com/riversideunified.org/matthewjeide/notes/w56b-de-multisim-2-3-5-xor-xnor-and-binary-adders

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Conclusion

Please answer in complete sentences. Minimum of three.

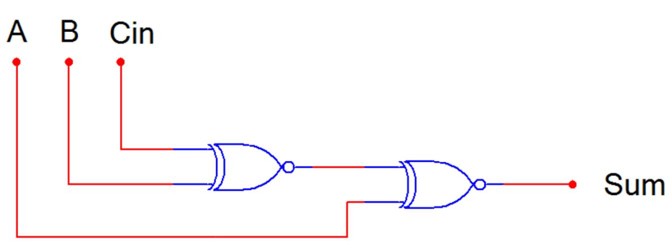
1. Perform the following binary additions using your 2-bit adder:

```
  0101      0011      1001      1010
+ 0111    + 1001    + 0101    + 1101
```

```
  01010011      01010001
+ 00110110    + 01010110
```

1100 = 12
1100 = 12
1110 = 14
(1)0111 = 7 (23 if overfill is accounted for)
10001001 = 137
10100111 = 167

2. The sum output of both the **half** and **full adders** could be implemented with XNOR gates instead of XOR gates (see below). Using Boolean algebra, prove that the output of the circuit below is equal to the sum output of a 2-bit adder.



A	B	Cin	Sum
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0

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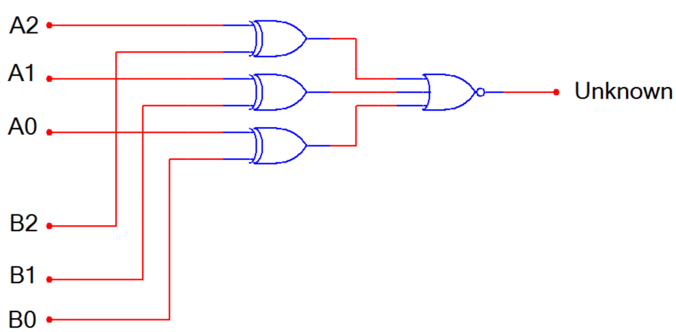
1	1	1	1

Above is the truth table, which is equivalent to an half adder and full adder (disregarding the Cout pin), this makes XOR’s very efficient for adding.

3. In addition to binary adders, another typical application of XOR gates is for magnitude comparators. Analyze the circuit shown below to determine its function. Note: Given that this circuit contains six inputs, and thus has $2^6 = 64$ possible output combinations, completing a truth table would not be the best approach to solving this problem.



$$(A2 \oplus B2) \oplus (A1 \oplus B1) \oplus (A0 \oplus B0)$$

