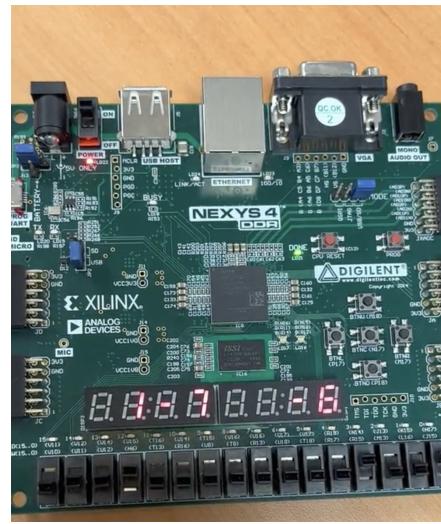


## Lab 3

This lab gave more scope towards understanding how peripheral devices can be interfaced to the FPGA board. In this case, we have a 4-bit adder with inputs. The inputs will represent positive and negative numbers but in 2's complements. [what is 2's complement]The lab implements in hardware a 4-bit adder with inputs representing positive and negative numbers in 2's complement. Verilog code implements this 4b adder in the simplest configuration - the ripple carry architectureVerilog code was successfully used in the simplest configuration. At each full-adder stage at each bit the sum if the bits are calculated. The output is displayed as a signed decimal digit in the seven-segment display. Take -4 and -4 as an example. As shown in the image below, -4 and -4 will result in an output of -8. This is indeed true. Another example is 1 and -7. The sum of the two bits is -6, which is also true.



**Figure 1 and 2.** In the above figure I have -4 and -4 as mu inputs (right). The result is -8. On the left, I have 1 and -7 as inputs in my 4b adder. Result is -6.

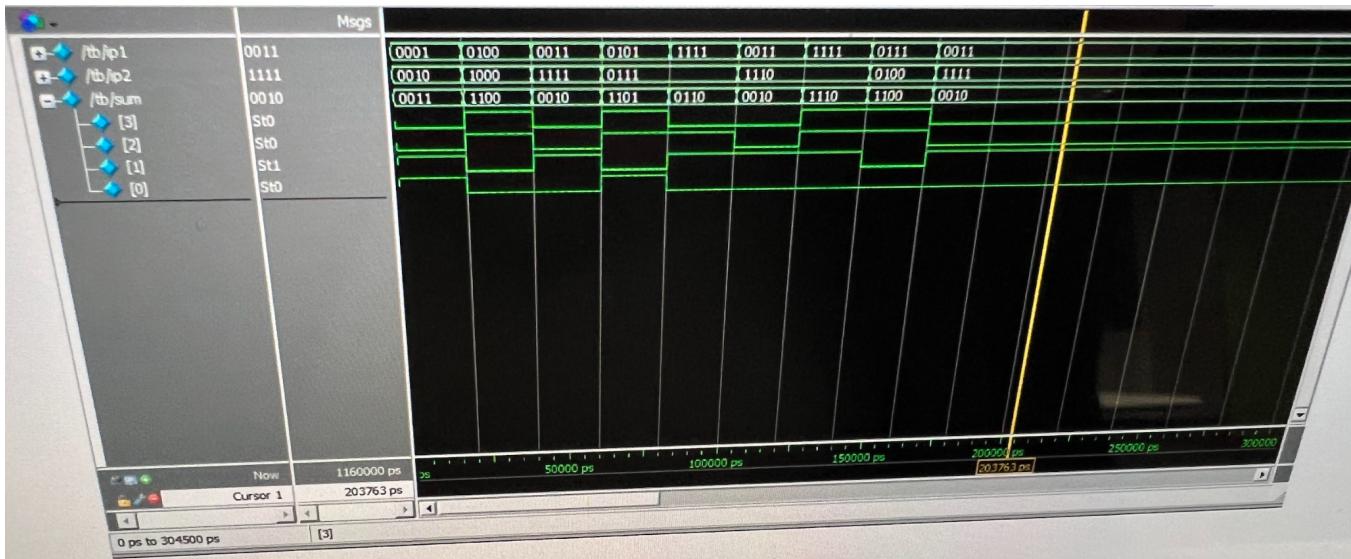
Something special to point out here is that if the operands have varying sign bits, overflow cannot happen. If the 4b operands have different sign bits, overflow cannot occur. For cases where the operands have identical sign bits, then sign bit in the adder result is compared with the sign bit of the sum, overflow has occurred and the green LED to the right of the seven segment display turns on, alerting the user to overflow.

Before moving on to the waveforms, I want to discuss when overflow does occur. When we have 2 bit 2's complement the range is -8 to 7, as per logical deduction. In the case we have -4 being added to -7, we will get E instead of -11 on the FPGA. This can be shown in figure 3.



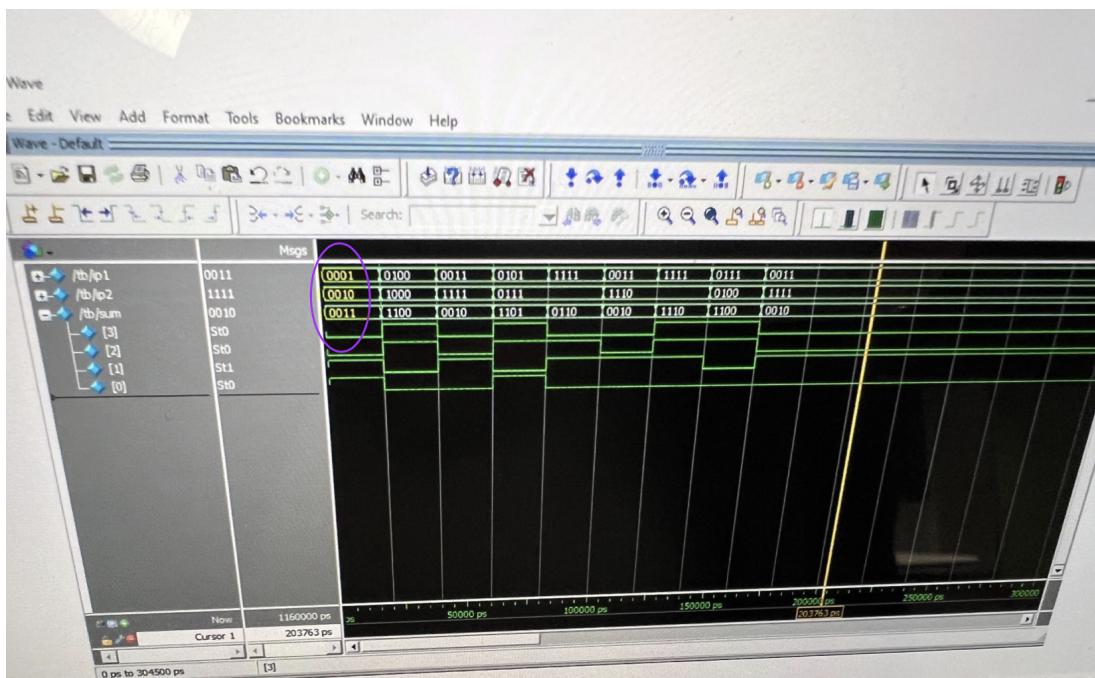
**Figure 4.** The above diagram shows that the sum of -4 and -7 results in E. This is a specific example in which the expected result is -11, which is out of the range (-8 to 7).

## Waveform Discussion



**Figure 3.** Waveform of 4b adder.

In figure 3, the important signals here are input 1, input2 and then the sum. Take the point (0001, 0010, 0011) as an example.



**Figure 4.** Waveform point indicating sum of two inputs that are each 4 bits.

The point is highlighted in figure 4. The 2 4 bits are added. In base 10, the numbers are one (0001), 2 (0010), and the output being 3 (0011).

Youtube video: <https://youtu.be/RnLeKeBOzSM>