1. (15 points) In class we have described a 64-bit ALU whose control input ALUop is composed of 1-bit Ainvert, 1-bit Bnegate, and 2-bit Operation from left to right. Re-design the ALU to meet the following new specification. You need to draw the circuit diagrams of each 1-bit ALU and the 64-bit ALU, similar to those shown in the lecture notes.
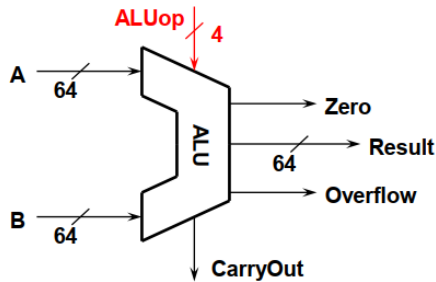
ALU Control (ALUop)	Function
1101	and
1111	or
1110	add
1010	substract
1000	set greater than
0011	nand

2. (36 points) Consider two unsigned binary numbers: M = 1010 and N = 0101.
    (a) (8 points) Write down each step of M × N according to version 1 of the multiply algorithm.
    (b) (8 points) Write down each step of M × N according to version 2 of the multiply algorithm.
    (c) (10 points) Write down each step of M ÷ N according to version 1 of the divide algorithm.
    (d) (10 points) Write down each step of M ÷ N according to version 2 of the divide algorithm

3. (20 points) Consider two decimal numbers: X = 785.3125 and Y = −13.125.
    (a) (10 points) Write down X and Y in the IEEE 754 single precision format. You must detail how you get the answers, or you will receive 0 point.
    (b) (5 points) Assuming X and Y are given in the IEEE 754 single precision format, show all the steps to perform X + Y and write the result in the IEEE 754 single precision format.
    (c) (5 points) Assuming X and Y are given in the IEEE 754 single precision format, show all the steps to perform X × Y and write the result in the IEEE 754 single precision format.

4. (9 points) Let W be the hexadecimal pattern 0xFF8E0E13. You must detail how you get the answers, or you will receive 0 point.
    (a) (3 points) What decimal number does W represent if it is a two's complement integer?
    (b) (3 points) What decimal number does W represent if it is an IEEE 754 floating-point number?
    (c) (3 points) Is it possible for W to be a RISC-V instruction? If yes, what is the corresponding assembly instruction? If not, why?

5. (20 points) Consider a new floating-point number representation that is only 16 bits wide. The leftmost bit is still the sign bit, the exponent is 5 bits wide and has a bias of 15, and the faction is 10 bits long. A hidden 1 to the left of the binary point is assumed. In this representation, any 16-bit binary pattern having 00000 in the exponent field and a non-zero fraction indicates a denormalized number: $(-1)^S \times (0 + \text{Fraction}) \times 2^{-14}$. Write the answers of (a), (b) and (c) in scientific notation, e.g., 1.0101×2^2.
    (a) (3 points) What is the smallest positive "normalized" number, denoted as a0?
    (b) (6 points) What is the largest positive "denormalized" number, denoted as a1? What is the second largest positive "denormalized" number, denoted as a2?
    (c) (4 points) Find the differences between a0 and a1, and between a1 and a2. Also describe what you observe and any implication from them.
    (d) (3 points) What decimal number does the binary pattern 1011110110100111 represent?
    (e) (4 points) Let U be the nearest representation of the decimal number 1.24; that is, U has the smallest approximation error. What is U? What is the actual decimal number represented by U?