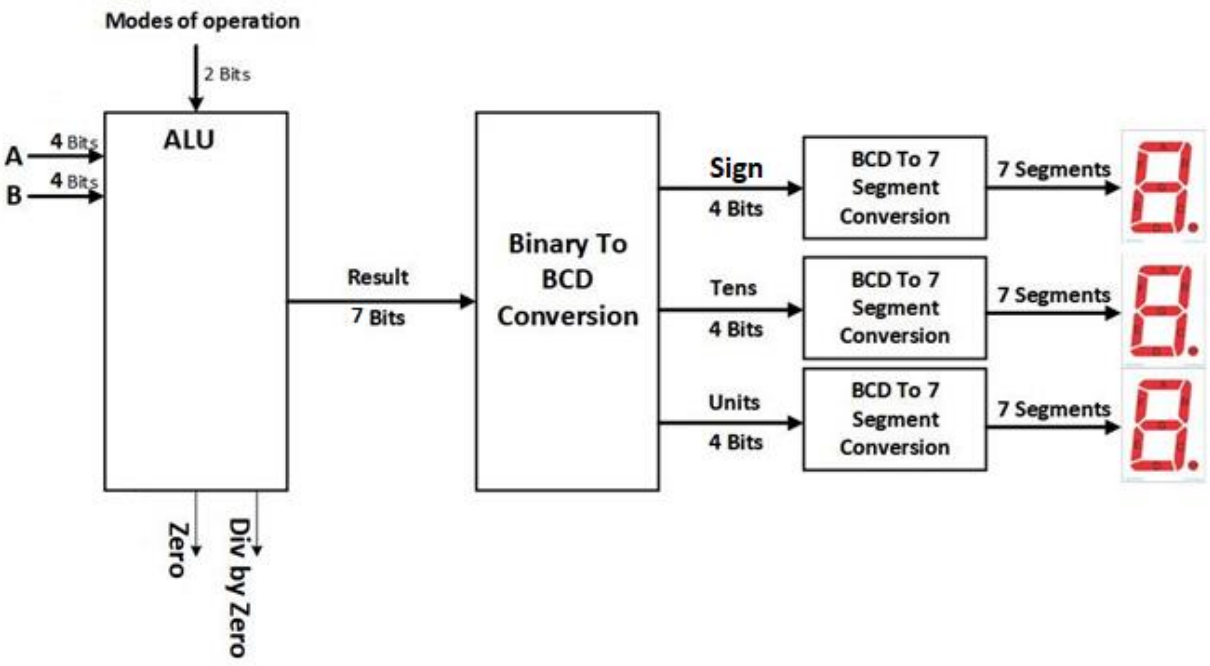
Introduction:

In this project, students are required to design and implement an arithmetic unit (ALU) that is capable of **adding**, **subtracting**, getting **reminder** and **multiplying** two signed magnitude numbers, and displays the result of the operation using three 7-segments. Some flags are used as well to show the status of the output.



Description:

The arithmetic unit takes two 4-bits signed inputs, A and B, (for example +7= 0111, -2= 1010) and an additional 2bits input called Mode of Operation, which informs the arithmetic unit which function to perform on A and B, the Output C is a 7-bits signed inputs (C is composed of 6-bits for the value and 1-bit for the sign):

1. **(00) Addition** $C = A + B$
2. **(01) Subtraction** $C = A - B$
3. **(10) Multiplication** $C = A \times B$
   The multiplication of $3 \times 3 = 9$, which in binary is $(11)_2 \times (11)_2 = (1001)_2$

4. **(11) Reminder**: result(C) = A % B
   A % 0 is forbidden and must output 0 and Div by Zero Flag must be asserted
   A % B, has the same sign as A.
   For example:
   - +2%+3 = +2
   - +2%-3 = +2
   - -2%+3 = -2
   - -2%-3 = -2

Flags:

- Sign Flag:
  The sign flag indicates if the result is negative. The flag is set to 1 if the result is negative and 0 otherwise (i.e., the output is zero or positive number).

- Zero Flag:
  The zero flag indicates if the result is zero. The flag is set to 1 if the result is zero and 0 otherwise.

- Div by Zero Flag:
  The divide by zero flag indicates if we divide by zero. The flag is set to 1 if B operand (the second operand) equals zero in reminder operation and 0 otherwise.

Work Distribution:

- Two of team members are responsible for the Addition and Subtraction operations and binary to BCD circuit and BCD to seven segments circuit
- one member implements the multiplication operation.
- one member implements the remainder operation.
- If the integration does not work, then the team will lose the integration grade only and each member will be graded upon his part in the project.

Notes:

- The outputs (Result C and sign flag) should be displayed on 3 seven segments and the other outputs (sign flag and divide-by-zero flag) should be displayed on leds).
- The input is entered through switches.
- You can use Full adder, half adder and multiplexor ICs in your design.
- IC number 7447 can be used to convert from BCD to seven segments, you can use it in converting result(C) to be displayed on seven segments.
- You need to implement circuit which convert from binary to BCD.

Project Phases:

	Thursday tutorials	Sunday tutorials
Project explanation	During the tutorial of 10 November 2022 (Thursday)	During the tutorial of 13 November 2022 (Sunday)
Phase0 (Team formation)	Before the midnight of 17 November 2022 (Thursday)	Before the midnight of 20 November 2022 (Sunday)
Phase1 (Simulation)	Before the midnight of 7 December 2022 **(Wednesday)**	Before the midnight of 10 December 2022 **(Saturday)**
Phase2 (Hardware)	During the tutorial of 22 December 2022 (Thursday)	During the tutorial of 25 December 2022 (Sunday)

Deliverables:

Note that submitting after the deadline in any phase will make you lose marks of that phase's grade.

- **Phase0:**
  - You need to form a team of 4 students **from the same tutorial** and write your information (ID, full name as in the grades sheet, email) in the sheet on the classroom.
  - In case you couldn't form a complete team before the deadline, you should write your sub-team information in the sheet (even if you were one student only)
  - Not writing your information before the deadline will deduct 5% of the project grade as a penalty. (This phase is not graded but you will be penalized if you missed it)

- **Phase1:**
  - You are required to implement the whole project using Logisim and **submit on the classroom** the following:
    a. All logisim files of the project. (You need to make the design hierarchy by implementing the different blocks in separate files to facilitate the debugging operation)
    - A PDF report including: (No need for printing it)
      - Your team personal information in the cover page.
      - Workload distribution of the team, stating which part is implemented by who. Integration is not a task implemented by one student, instead it is a task for the whole team to take part in.
      - 4 tables of the test cases you have tested for the 4 parts of the project. Each table should include 5 columns (first operand, second operand, SW actual output, expected output, Status) all values should be written in binary. (Try different test cases to cover all possible scenarios and corner cases)
- **Phase2:**
  - You are required to implement your project using actual ICs and breadboards (i.e. Hardware implementation) and submit it during your tutorial.
  - You are required to **submit on the classroom** the PDF report you submitted in phase1 with one modification. You should add another column "HW actual output" to all test cases' tables and write all your HW results in that column.
  - You should **submit on the classroom** a demo video. You need to show in that video, all test cases you wrote in the report while commenting on the results whether it is correct or incorrect. (During the video, all input switches and outputs should be clearly shown)