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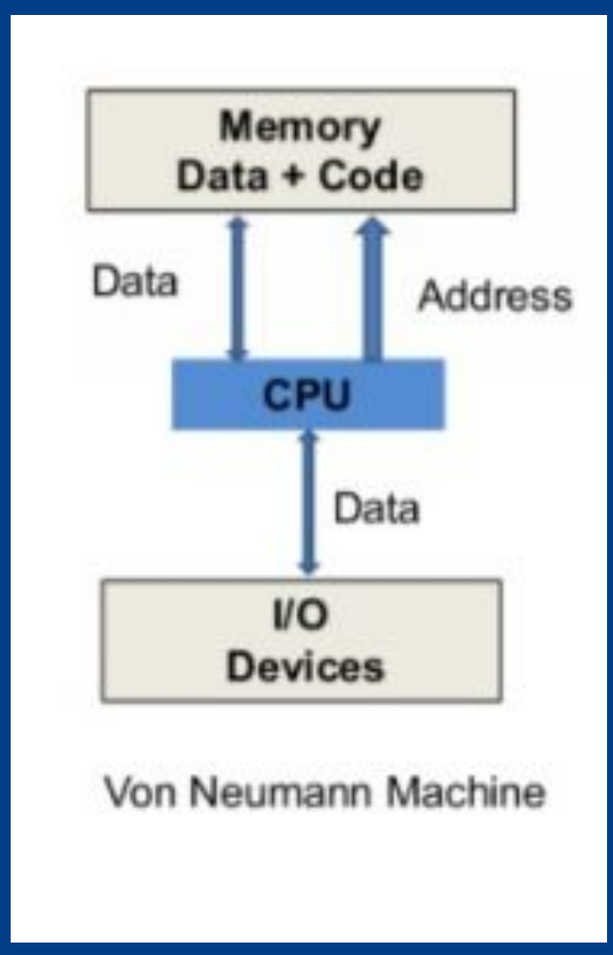
ROUND-2

I-CHIP

In the previous problem statement, you were assigned to design CalC which was used in microprocessors required to process the sensory data.

Initially, your seniors were assigned the task to make the control unit for such microprocessors but as they are busy in their internships, you have been now assigned the task of designing a prototype of a complete microprocessor. The prototype will be tested on a given set of instructions and data.

The microprocessor is supposed to follow Von Neumann Architecture and should be an accumulator based processor (The output of ALU is always stored in the accumulator).



Von Neumann Machine

Read more about Von Neumann architecture: Von-Neumann Model

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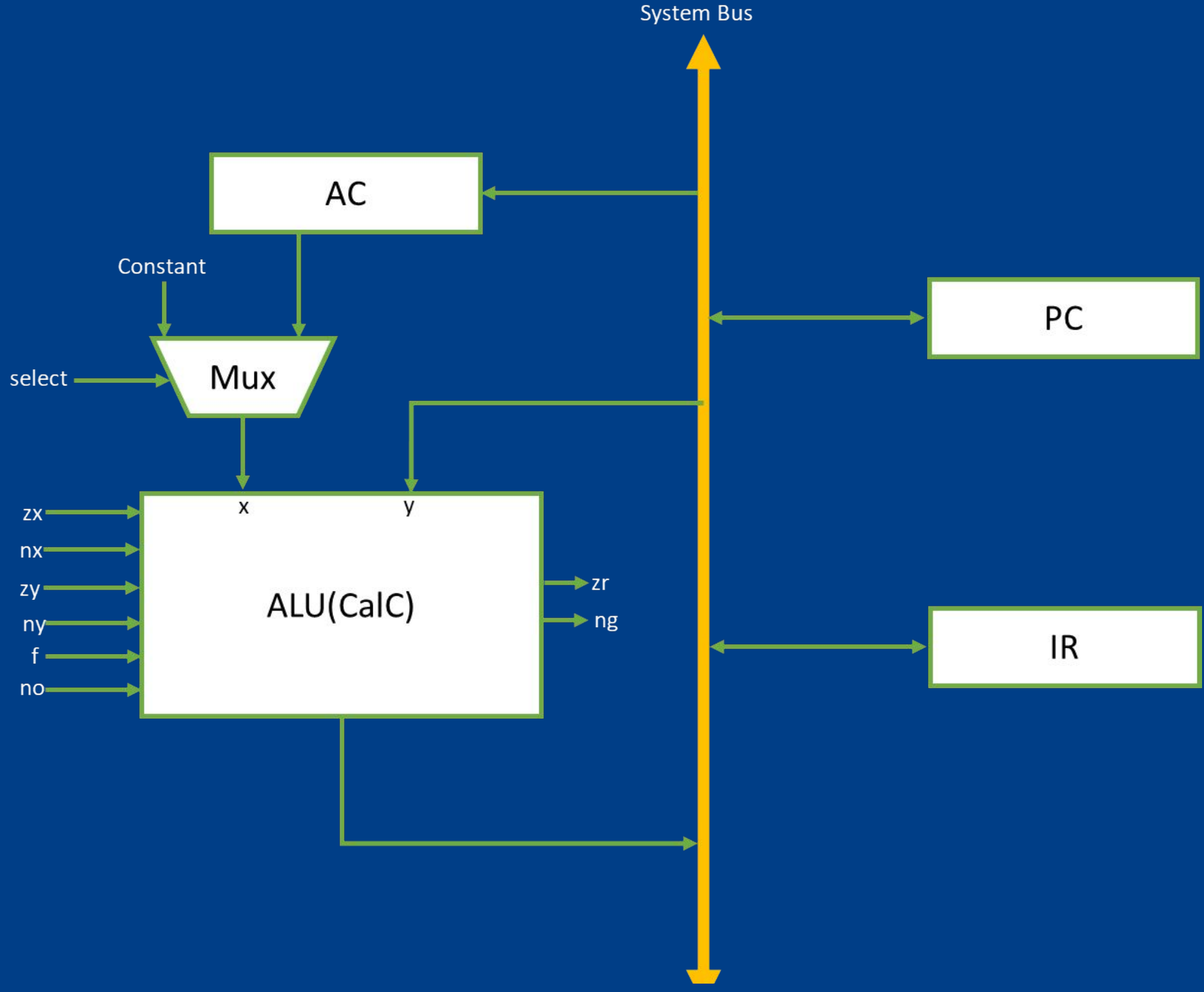
TASK:

Design a 16-bit CPU which will use an 2KB (1K x 16) memory. Address for code segment and data segment of memory is 0-0x190 and 0x191-0x3FF respectively.
Read more about Memory Designing: Internal Organization of Memory Chips

Use the CalC already designed in previous problem as ALU of this CPU, Do not worry if you were not able to find the appropriate combination of control bits for certain functions, check the linked table for correct combination of control bits for all the functions: PS1 Control Bits

Note: CalC was a 8-bit ALU, make required changes in it's design to use it as a 16-bit ALU.

The CPU architecture is shown below :



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The instruction bits are divided into 3 parts :-

Addressing Mode (1 bit)	Opcode (5 bits)	Memory Address (10 bits)

1. The 1st bit represents the Addressing Mode :
   - '0' for Direct Addressing.
   - '1' for Indirect Addressing.

2. The next 5 bits represent the Opcode for the instruction.
3. The next 10 bits represent the Address of the memory that is needed in the instruction.

You can learn the differences between these two addressing modes from the given link: Direct and Indirect Addressing Modes

The opcode and the functions they perform have been mentioned on the next page.

Note - For each opcode, you need to find the corresponding control signals that should be provided to CalC.

Opcode	Function
00000	Set output to decimal value 0
00001	Set output to decimal value 1
00010	Set output to decimal value -1
00011	Set output to input x
00100	Set output to input y
00101	Set output to not of input x
00110	Set output to not of input y
00111	Set output to negative of input x
01000	Set output to negative of input y
01001	Set output to increment of input x by 1
01010	Set output to increment of input y by 1
01011	Set output to decrement of input x by 1
01100	Set output to decrement of input y by 1
01101	Perform addition on the two inputs
01110	Perform subtraction: x-y
01111	Perform subtraction: y-x
10000	Perform bitwise 'and' between the two inputs
10001	Perform bitwise 'or' between the two inputs
10010	Read from memory store in the accumulator
10011	Write the output to memory
101000	Jump to given instruction address
10101	Jump to the given instruction address if the last output was zero
10110	Jump to the given instruction address if the last output was negative
10111	End the program

EXAMPLE:

Let's discuss a simple example of how the instructions are executed in the CPU:-

We are given a set of instructions as follows :-

Address	**Instruction**
0000000000	0100100110010001
0000000001	0011010110010010
0000000010	0100110110010001

The Data stored in Memory is given as follows :-

Address	**Data**
0110010001	2
0110010010	4

The CPU will follow given steps to execute the given set of instructions:

1. The PC is initialized to '0000000000'. So, the first instruction from the memory will be fetched using address from PC. The fetched instruction will be stored in IR.

So, at this point values of various registers will be :-

PC	0000000000
IR	0100100110010001
AC	0

2. Now, the instruction will be decoded and accordingly control signals will be generated depending on the opcode.
Here, the opcode is - 10010, which is used for read operation.
The addressing mode used is Direct (0).
The memory address which is to be read is '0110010001' . The data stored at the memory address '0110010001' will be stored in accumulator (AC).

So, the values of various registers at this stage will be :-

PC	0000000000
IR	0100100110010001
AC	2

3. Now, the PC will be incremented by 1 and next instruction stored at '0000000001' will be fetched and stored in IR.

The values of various registers at this point will be :-

PC	0000000001
IR	0011010110010010
AC	2

4. Now, the instruction is decoded and control signals will be generated accordingly.
Here, the opcode is - 01101, which is used for addition of two numbers.
The addressing mode used is Direct (0).
The memory address which is to be read is '0110010010' . The data stored at the memory address '0110010010' will be added to the value stored in accumulator.
The output after addition will be stored back in accumulator.
So, the values of various registers at this point will be :-

PC	0000000001
IR	0011010110010010
AC	2 + 4 = 6

5. Now, the PC will be incremented by 1 and next instruction stored at '0000000010' will be fetched and stored in IR.
The values of various registers at this point will be :-

PC	0000000010
IR	0100110110010001
AC	6

6. Now, the instruction will be decoded and accordingly control signals will be generated depending on the opcode.
Here, the opcode is - 10011, which is used for writing operation.
The addressing mode used is Direct (0).
The memory address to which the value has to be written is '0110010001' .
The data stored in accumulator(AC) will be written at the memory address '0110010001' .

So, the values of various registers at this stage will be :-

PC	0000000010
IR	0100110110010001
AC	6

The new values stored in the Memory will be :-

Address	Data
0110010001	6
0110010010	4

TESTING :

You will be provided two text files. One will contain the set of instructions to be executed. Other will contain the data to be stored in the memory.

Link for Program file: Program.txt
Link for Data file: Data.txt

Upload the program in the code segment of the Memory and the data in the data segment of the Memory.

Create a testbench with a clock cycle of 100 MHz.

Run the program, execute all the instructions in a sequential order. After complete execution of all the instructions, write the data segment of Memory in an output.txt file.

EVALUATION SCHEME :

1. 500 points will be awarded for completing the problem statement.
2. The teams completing the problem statement will be awarded extra points in the priority order of their time of simulations i.e. the teams which are able to completely execute the instruction set in less no. of clock cycles will be given priority.

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SUBMISSION:

Submit a zip folder containing following files :

1. Verilog files of the design modules and testbench.
2. Output text file containing the final data segment of Memory.
3. A pdf file explaining your approach towards the problem.

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