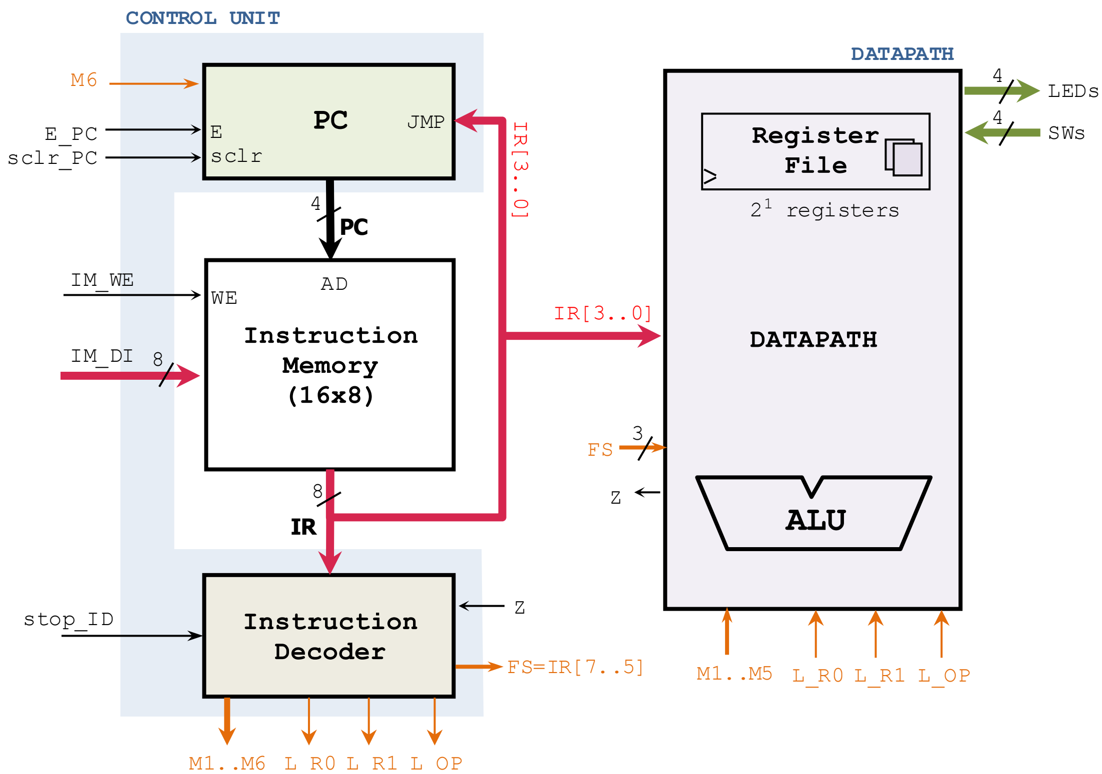
Solutions - Homework 4

(Due date: April 12th @ 7:30 pm)

Presentation and clarity are very important! Show your procedure!

PROBLEM 1 (30 PTS)

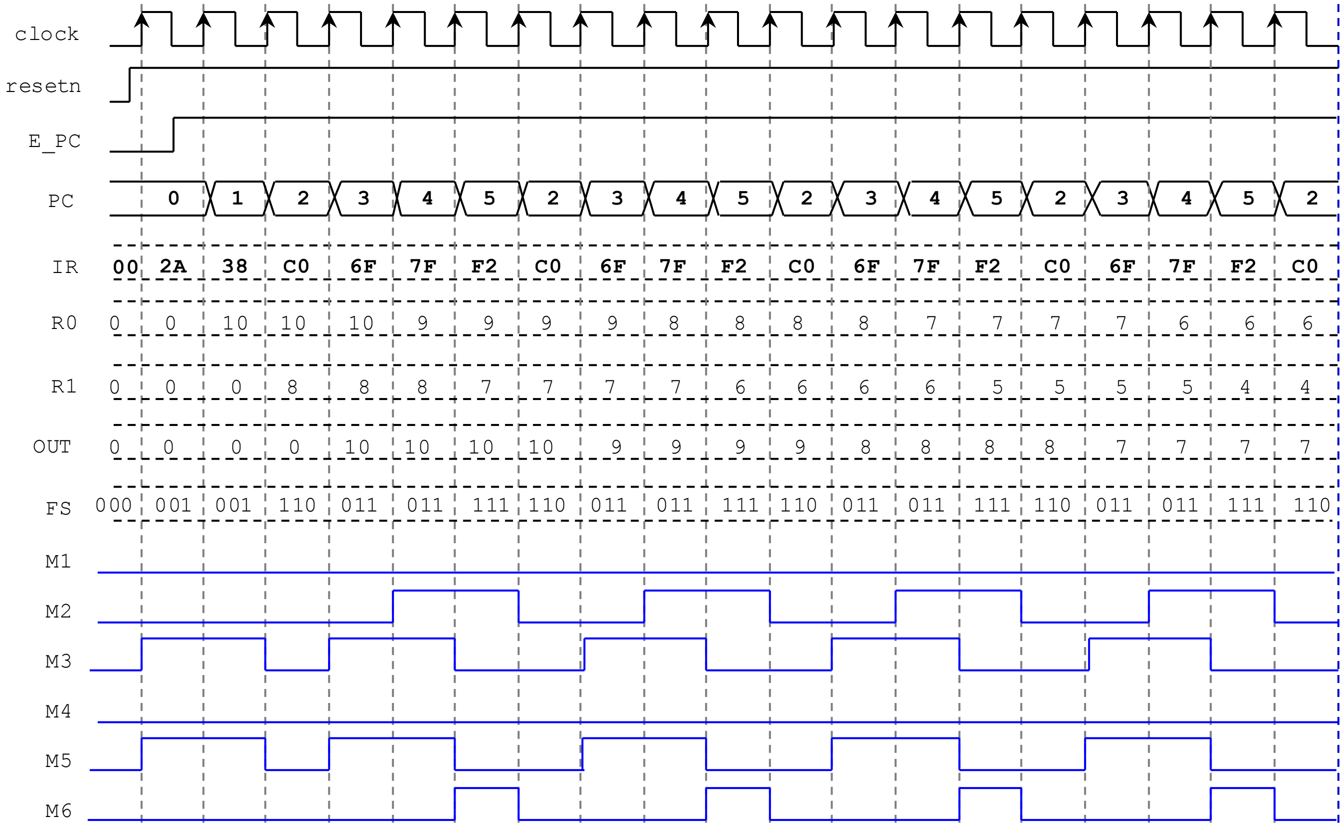
- **"VBC (Very Basic Computer)"**: 2 registers, 16-word Instruction Memory (IM), 8 bits per instruction (see Notes – Unit 6).

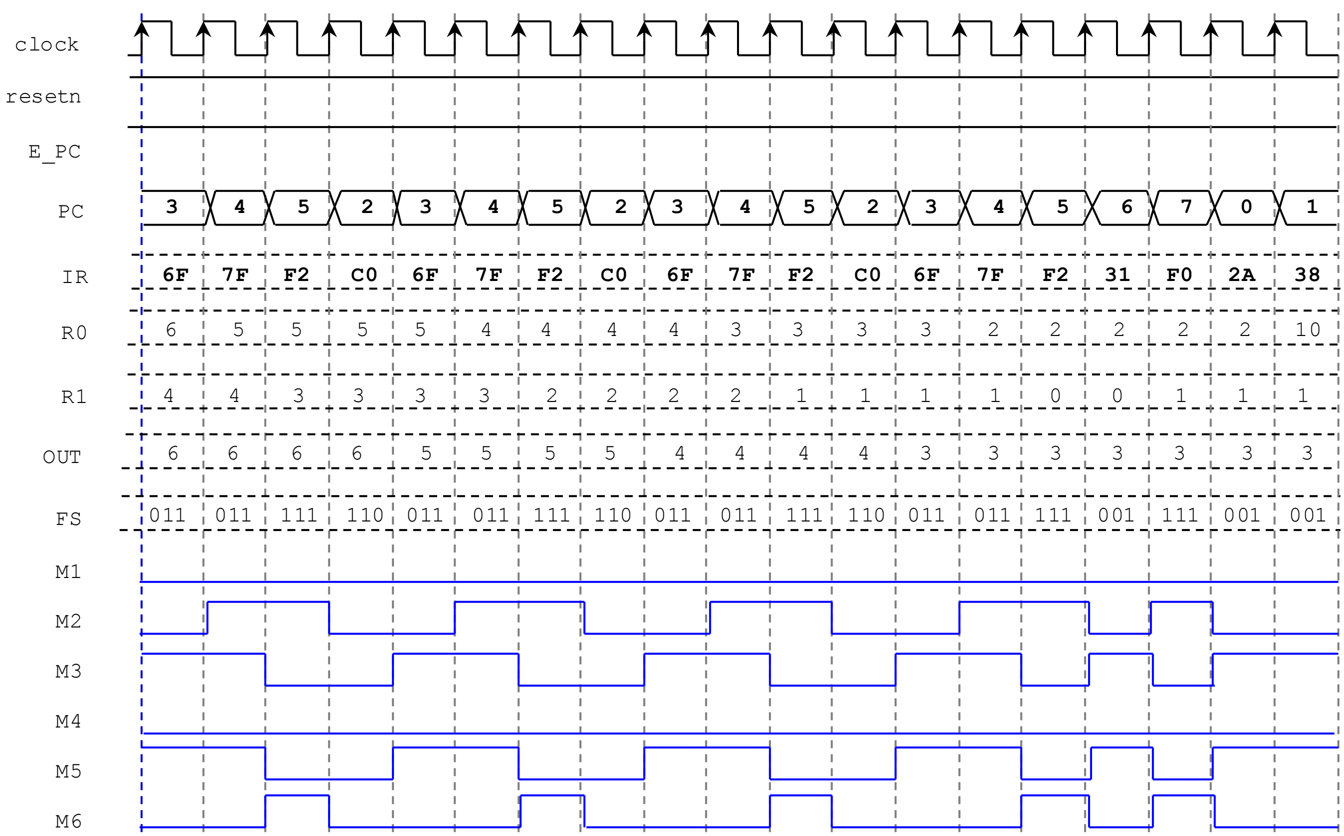


- ✓ Write an assembly program for a counter from 10 down to 3: 10, 9, … 3, 10, 9, … The count must be shown on the output register (**OUT**). Use labels to specify any address that an instruction may jump to. You can only have up to 16 instructions.
  * To decrement the value of a register by 1 (e.g. R0), you can use: addi R0,15 ≡ R0 ← R0-1.
- ✓ Provide the contents of the Instruction Memory. If some instruction bits are unused, you can assign 0's.

Address	Instruction Memory	Assembly Instruction
0000	00101010	start: loadi R0, 10
0001	00111000	loadi R1, 8
0010	11000000	loop: out R0
0011	01101111	addi R0,15
0100	01111111	addi R1,15
0101	11110010	jnz R1, loop
0110	00110001	loadi R1,1
0111	11110000	jnz R1, start
1000		
1001		
1010		
1011		
1100		
1101		
1110		
1111		

✓ Complete the timing diagram for the execution of the previous program. Use unsigned decimal values for R0, R1, OUT, and PC. Specify IR in hexadecimal. (18 pts)
IM: Array of registers. In this case, when reading, output data appears as soon as address is ready.
Assumptions: the program is already in IM. Also: `sclr_PC=0, IM_WE=0, stop_ID=0.`





PROBLEM 2 (18 PTS)

- "**Simple Computer**": 8 registers, 64-word Instruction Memory (IM), 16 bits per instruction (see Notes – Unit 6).
  - ✓ For each of the following instructions, indicate the bits for the instruction fields (if they do not apply, write 'NA'), and the instruction memory contents (if some bits are unused, you can assign 0's). (8 pts)

Address	Instruction	OPCODE	DR	SA	SB	OP	AD	Instruction Memory contents
0	LDI R7,5	1001100	111	---	NA	101	NA	1001100111---101
1	LDI R3,2	1001100	011	---	NA	010	NA	1001100011---010
2	LDI R2,7	1001100	010	---	NA	111	NA	1001100010---111
3	SUB R0,R3,R2	0000101	000	011	010	NA	NA	0000101000011010
4	ADD R6,R7,R0	0000010	110	111	000	NA	NA	0000010110111000
5	ST R3,R6	0100000	---	011	110	NA	NA	0100000---011110
6	XOR R0,R6,R2	0001010	000	110	010	NA	NA	0001010000110010
7	LD R5,R3	0010000	101	011	---	NA	NA	0010000101011---
8	BRZ R6,-4	1100000	NA	110	NA	NA	111100	1100000111110100
9	SHR R7,R2	0001101	111	---	010	NA	NA	0001101111---010
10	JMP R3	1110000	NA	011	NA	NA	------	1110000---011---

  - ✓ Emulate the execution of the program by completing the state of the registers (use hexadecimal values) after the instruction pointed by PC is executed. Then, complete the PC (use binary values) of the next instruction. Complete it until the JMP instruction is reached (execute this instruction as well). (10 pts)

PC	R0	R2	R3	R5	R6	R7
000000	0000	0000	0000	0000	0000	0005
000001	0000	0000	0002	0000	0000	0005
000010	0000	0007	0002	0000	0000	0005
000011	FFFB	0007	0002	0000	0000	0005
000100	FFFB	0007	0002	0000	0000	0005
000101	FFFB	0007	0002	0000	0000	0005
000110	0007	0007	0002	0000	0000	0005
000111	0007	0007	0002	0000	0000	0005
001000	0007	0007	0002	0000	0000	0005
000100	0007	0007	0002	0000	000C	0005
000101	0007	0007	0002	0000	000C	0005
000110	000B	0007	0002	0000	000C	0005
000111	000B	0007	0002	000C	000C	0005
001000	000B	0007	0002	000C	000C	0005
001001	000B	0007	0002	000C	000C	0003
001010	000B	0007	0002	000C	000C	0003

PROBLEM 3 (17 PTS)

- "**Simple Computer**": 8 registers, 64-word IM, 16 bits per instruction (see Notes - Unit 6)
  - ✓ Write an assembly program that stores numbers from 37 down to 25 in Data Memory (DM) on addresses 0 to 12. Use labels to specify any address that an instruction may jump to.
    - Note that you can only have up to 64 instructions.
    - The ALU treats data as signed numbers. Thus, data on the registers (R0 – R7) and Data Memory (16 bits) is signed.
  - ✓ Provide the contents of the Instruction Memory (IM) and its addresses.

address	DM
000000	25
000001	24
000010	23
000011	22
000100	21
000101	20
000110	1F
000111	1E
001000	1D
001001	1C
001010	1B
001011	1A
001100	19
...	

Address	Instruction Memory	Assembly Instructions
000000	1001100 010 --- 101	start: ldi R2,5
000001	1001100 110 --- 110	ldi R6,6
000010	1000010 110 110 110	adi R6,R6,6
000011	0000000 100 110 ---	mova R4,R6
000100	0000010 110 100 110	add R6,R4,R6
000101	0000001 110 110 ---	loop: inc R6,R6
000110	0100000 --- 100 110	st R4,R6
000111	1100000 111 100 001	brz R4,-7
001000	0000110 100 100 ---	dec R4,R4
001001	1110000 --- 010 ---	jmp R2

PROBLEM 4 (20 PTS)

- "**PicoBlaze MicroProcessor**": 16 registers, 1024-word Instruction Memory, 18 bits per instruction (see Notes – Unit 6).
  - ✓ Emulate the execution of this program by completing the state of the registers (hexadecimal values) and the status flags (C, Z) after the instruction pointed by PC is executed. Then, complete the PC (hexadecimal values) of the next instruction and update SP (binary values). Complete it until the `jump` instruction (`003`) is reached (execute this instruction as well).

```
Address | Assembly Program
  000   | main: load s3,05
  001   |       load s4,03
  002   |       call umult
  003   |       jump main
  ...   |       ...

  067   | umult: load s5,00
  068   |        load s7,08
  069   | loop:  sr0 s4
  06A   |        jump nc, sh_p
  06B   |        add s5, s3
  06C   |  sh_p: sra s5
  06D   |        sra s6
  06E   |        sub s7,01
  06F   |        jump nz, loop
  070   |        return
  ...   |        ...
```

PC	SP	s3	s4	s5	s6	s7	C	Z
000	11111	05	00	00	00	00	0	0
001	11111	05	03	00	00	00	0	0
002	11111	05	03	00	00	00	0	0
067	11110	05	03	00	00	00	0	0
068	11110	05	03	00	00	08	0	0
069	11110	05	01	00	00	08	1	0
06A	11110	05	01	00	00	08	1	0
06B	11110	05	01	05	00	08	0	0
06C	11110	05	01	02	00	08	1	0
06D	11110	05	01	02	80	08	0	0
06E	11110	05	01	02	80	07	0	0
06F	11110	05	01	02	80	07	0	0
069	11110	05	00	02	80	07	1	1
06A	11110	05	00	02	80	07	1	1
06B	11110	05	00	07	80	07	0	0
06C	11110	05	00	03	80	07	1	0
06D	11110	05	00	03	C0	07	0	0

06E	11110	05	00	03	C0	06	0	0
06F	11110	05	00	03	C0	06	0	0
069	11110	05	00	03	C0	06	0	1
06A	11110	05	00	03	C0	06	0	1
06C	11110	05	00	01	C0	06	1	0
06D	11110	05	00	01	E0	06	0	0
06E	11110	05	00	01	E0	05	0	0
06F	11110	05	00	01	E0	05	0	0
069	11110	05	00	01	E0	05	0	1
06A	11110	05	00	01	E0	05	0	1
06C	11110	05	00	00	E0	05	1	1
06D	11110	05	00	00	F0	05	0	0
06E	11110	05	00	00	F0	04	0	0
06F	11110	05	00	00	F0	04	0	0
069	11110	05	00	00	F0	04	0	1
06A	11110	05	00	00	F0	04	0	1
06C	11110	05	00	00	F0	04	0	1
06D	11110	05	00	00	78	04	0	0
06E	11110	05	00	00	78	03	0	0
06F	11110	05	00	00	78	03	0	0
069	11110	05	00	00	78	03	0	1
06A	11110	05	00	00	78	03	0	1
06C	11110	05	00	00	78	03	0	1
06D	11110	05	00	00	3C	03	0	0
06E	11110	05	00	00	3C	02	0	0
06F	11110	05	00	00	3C	02	0	0
069	11110	05	00	00	3C	02	0	1
06A	11110	05	00	00	3C	02	0	1
06C	11110	05	00	00	3C	02	0	1
06D	11110	05	00	00	1E	02	0	0
06E	11110	05	00	00	1E	01	0	0
06F	11110	05	00	00	1E	01	0	0
069	11110	05	00	00	1E	01	0	1
06A	11110	05	00	00	1E	01	0	1
06C	11110	05	00	00	1E	01	0	1
06D	11110	05	00	00	0F	01	0	0
06E	11110	05	00	00	0F	00	0	1
06F	11110	05	00	00	0F	00	0	1
070	11110	05	00	00	0F	00	0	1
003	11111	05	00	00	0F	00	0	1

PROBLEM 5 (15 PTS)

- Attach a printout of your Project Status Report (no more than 3 pages, single-spaced, 2 columns). This report should contain the current status of the project, including more details about the design and its components. You **MUST** use the provided template (`Final Project - Report Template.docx`).