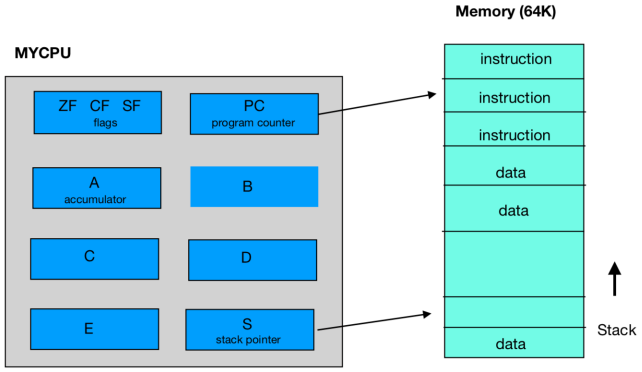
CMPE 230 Systems Programming

Project (due May 27th)

(This project can be implemented in groups of at most two students.)

This project is to be done with Python. In this project, you will implement (i) an assembler and (ii) an execution simulator for a hypothetical CPU called CPU230. CPU230 is illustrated in the following figure:



Each instruction has fixed length of 3 bytes with the following format:

Opcode	Adressing mode	Operand
6 bits	2 bits	16 bits

Addressing mode bits are as follows:

Bits(binary)	Addressing mode
00	operand is immediate data
01	operand is in given in the register
10	operand's memory address is given in the register
11	operand is a memory address
Note that registers are represented as bit patterns (here given in hex): PC=0000, A=0001, B=0002, C=0003, D=0004, E=0005, S=0006.	

Instructions are as follows:

Instruction	Instruction code (hex)	Operand	Meaning	Flags set
HALT	1		Halts the CPU.	
LOAD	2	immediate memory register	Loads operand onto A .	
STORE	3	memory register	Stores value in A to the operand.	
ADD	4	immediate memory register	Adds operand to A. Perform the addition by treating all the bits as unsigned integer.	CF,SF, ZF
SUB	5	immediate memory register	Subtracts operand (OPR) from A. Implement it as ADD instruction as follows: A - OPR = A + (-OPR) = A + not(OPR) + 1	CF,SF, ZF
INC	6	immediate	increments operand (equivalent to add 1)	SF, ZF, CF

		memory register		
DEC	7	immediate memory register	decrements operand (equivalent to sub 1)	SF, ZF, CF
XOR	8	immediate memory register	Bitwise XOR operand with A and store result in A.	SF, ZF
AND	9	immediate memory register	Bitwise AND operand with A and store result in A.	SF, ZF
OR	A	immediate memory register	Bitwise OR operand with A and store result in A.	SF, ZF
NOT	B	immediate memory register	Take complement of the bits of the operand.	SF, ZF
SHL	C	register	Shift the bits of register one position to the left.	SF, ZF, CF
SHR	D	register	Shift the bits of register one position to the right.	SF, ZF
NOP	E		No operation.	
PUSH	F	register	Push a word sized operand (two bytes) and update S by subtracting 2.	
POP	10	register	Pop a word sized data (two bytes) into the operand and update S by adding 2.	
CMP	11	immediate memory register	Perform comparison with A-operand and set flag accordingly., i.e. A-OPR	SF, ZF, CF
JMP	12	immediate	Unconditional jump. Set PC to address.	
JZ JE	13	immediate	Conditional jump. Jump to address (given as immediate operand) if zero flag is true.	
JNZ JNE	14	immediate	Conditional jump. Jump to address (given as immediate operand) if zero flag is false.	
JC	15	immediate	Conditional jump. Jump if carry flag is true.	
JNC	16	immediate	Conditional jump. Jump if carry flag is false.	
JA	17	immediate	Conditional jump. Jump if above.	
JAE	18	immediate	Conditional jump. Jump if above or equal.	
JB	19	immediate	Conditional jump. Jump if below.	
JBE	1A	immediate	Conditional jump. Jump if below or equal.	
READ	1B	memory register	Reads a character into the operand.	
PRINT	1C	immediate memory register	Prints the operand as a character.	

Note that memory address can be given as **`[xxxx]`** or **`[r]`** where **`xxxx`** is a hexadecimal number or **`r`** where **`r`** is a register name.

Labels can also be used. A label: marks the address, **`xxxx`**, at the point it is defined. Wherever you use a label, you should substitute the marked address **`xxxx`** for the label.

Note that when you add two n-bit numbers, you can get 1+n bits as a result. You store the leftmost (most significant) single bit in CF. You store the other n bits in the destination location. In this project, n is 16 bits.

The assembler you build will be called **cpu230assemble** and the execution simulator will be called **cpu230exec**. They will be used as follows. Suppose you are given a assembly program given in file prog.asm. The following command will assemble the program and produce the binary output prog.bin.

```
> cpu230assemble prog.asm
```

The following program will execute the binary

```
> cpu230exec prog.bin
```

The above process is illustrated in the example below:

Assembly source code: prog.asm	Assemble	Assembled program : prog.bin	Execute	Output
LOAD 'A' STORE C LOAD MYDATA STORE B LOAD 0004 STORE D LOOP1: PRINT C LOAD C STORE [B] INC C INC B INC B DEC D JNZ LOOP1 HALT MYDATA:	cpu230assemble prog.asm →	080041 0D0003 08002D 0D0002 080004 0D0004 710003 090003 0E0002 190003 190002 190002 1D0004 530012 040000	cpu230exec prog.bin →	A B C D

Note also that in the above example, ascii codes of 'A', 'B', 'C', 'D' and 'E' are stored at the memory addresses **002D, 002F, 0031, 0033, 0035**.

Grading

Your project will be graded according to the following criteria:

Documentation (written document describing how you implemented your project)	12%
Comments in your code	8%
Implementation and tests	80%

Late Submission

If the project is submitted late, the following penalties will be applied:

- 0 < hours late <= 24 : 25%
- 24 < hours late <= 48 : 50%
- hours late > 48 : 100%

Timestamping

Project file should include your names in it. Please timestamp your project file using https://opentimestamps.org/ before you submit it. Keep the project file and its corresponding timestamp .ots file.