CSE 321a: Computer Organization (1)
Third Year, Computer & Systems Engineering

Assignment #1

Due date: **Wednesday, 19th October, 2016**

1. Consider two different processors, P_1 and P_2, that implement the same instruction set. There are three classes of instructions (A, B, and C) in the instruction set. The clock speed and CPI of each instruction class is given by the following table:

Processor	**Clock speed**	**CPI_A**	**CPI_B**	**CPI_C**
P_1	200 MHz	4	9	6
P_2	160 MHz	5	10	3

Suppose it takes 30 ms for P_1 to execute a benchmark program X (that contains one-million instructions), while it takes 31.25 ms for P_2 to execute the same program.

(a) How many cycles each processor takes on average to execute one instruction from program X?

(b) What is the number of each class of instructions in program X?

2. In a hypothetical computer, the processor has four registers: a 16-bit Program Counter (PC), a 20-bit Accumulator (AC), a 14-bit Counter (CTR), and a 14-bit Pointer (PTR). The memory is divided into words each of which is 20-bit long. Each word can hold either an instruction or a piece of data. For each instruction X, the six most significant bits (denoted by $X_{19\text{-}14}$) represent an opcode. The rest of the instruction (denoted by $X_{13\text{-}0}$) can be either an address or a value of an operand. Operands that represent signed numbers are interpreted according to the sign-an-magnitude representation. The table below explains some of the instructions supported by the processor.

Opcode (binary)	**Operation**
000001	Reset AC.
000011	Load PTR with $X_{13\text{-}0}$.
000101	Load CTR with $X_{13\text{-}0}$.
001000	Load AC from a memory location whose address is $X_{13\text{-}0}$.
001001	Store AC into a memory location whose address is $X_{13\text{-}0}$.
001011	Add to AC the value of the signed number stored at the memory location whose address is in PTR.
001100	Add to AC the squared value of the signed number stored at the memory location whose address is in PTR.
001110	Calculate the (positive) square root for the (positive) signed number stored in AC and save the result back to AC.
110010	If X_0 is 1, increment PTR (by one); otherwise, decrement PTR (by one).
110101	If X_0 is 1, increment CTR (by one); otherwise, decrement CTR (by one).
110110	If CTR is not 0, branch to an instruction whose address is obtained by subtracting $X_{13\text{-}0}$ from PC (*i.e.*, decrement PC by $X_{13\text{-}0}$); otherwise, continue normally (*i.e.*, do not change PC).
111110	Halt execution.

(a) In this hypothetical computer, which memory locations can be used to store instructions, and which memory locations can be used to store data? Specify the full range of addresses in each case.

(b) Given the following program:

Address (Hexadecimal)	**Contents (Hexadecimal)**
D47C	04000
D47D	0FC98
D47E	14003
D47F	33FFF
D480	C8001
D481	D7FFE
D482	D8004
D483	38000
D484	27C9B

Show, using the table below, the execution trace of that program by filling in the contents of every register and memory location after the fetch cycle and after the execute cycle of every instruction. All values are in hexadecimal.

Instruction	**Cycle**	**PC**	**AC**	**CTR**	**PTR**	**Location: 3C98**	**Location: 3C99**	**Location: 3C9A**	**Location: 3C9B**
Initially	---	D47C	C0FFE	3E0D	02B0	8000C	00003	80004	0BEEF
04000	Fetch	D47D	C0FFE	3E0D	02B0	8000C	00003	80004	0BEEF
	Execute	D47D	00000	3E0D	02B0	8000C	00003	80004	0BEEF
0FC98	Fetch	…	…	…	…	…	…	…	…
	Execute	…	…	…	…	…	…	…	…
14003	Fetch	…	…	…	…	…	…	…	…
	Execute	…	…	…	…	…	…	…	…

(c) What does the program compute?

(d) Suppose that it takes 5 clock cycles in order for the processor to read a word from or write a word to the memory. Suppose further that the processor takes 3 clock cycles on average to execute an instruction; that is in addition to the time taken to fetch an operand from the memory or write a result to the memory. Given that the processor is clocked at a rate of 100MHz, how much time does it take for the program to be executed? Justify your answer.