Practical Session Week 4

Objectives

1. To understand ughput, CPI, CPU time, clock rate, MIPS and FLOPs
2. To solve CPU xercises

Tasks

1. Given that the ion set has the width of 8 bits:
   - What is the full instruction set size? **Answer: 2^8=256**
   - What would the opcodes of the last 2 instructions be in HEX? **Answer: FF_{16}=1111 1111$_2$, FE_{16}=1111 1110**

2. Which plane has better performance?

Plane	London to Moscow	Passengers
Airplane 1	6 hours	100
Airplane 2	3 hours	20

- **Response time**: The time between the start and completion of a task. It includes time spent executing on the CPU, accessing disk and memory, waiting for I/O and other processes, and operating system overhead.
- **Throughput**: The total amount of work done in a given time.
- **CPU execution time**: Total time a CPU spends computing on a given task (excludes time for I/O or running other programs).

Airplane 2 is two times faster in terms of flying time, but slower in terms of throughput as throughput1=16.6 passengers/hour and troughput2=6.6 passengers/hour

3. Basic concepts :
   - A given program will require
     - some number of instructions (machine instructions)
     - some number of clock cycles
     - some number of seconds
   - The **clock rate** (cycles per second) is the inverse of the **clock cycle time** (seconds per cycle), for example, if a computer has a clock cycle time of 5 ns, the clock rate is (*1 / 5 x 10^{-9} sec)=200MHz*
   - **CPI** (cycles per instruction). The CPI is the average number of cycles per instruction
   - **CPU time** is the time to execute a given program
   - **Different instructions take different number of CPU cycles**, e.g., division takes more cycles than addition, floating point instructions take more cycles than fixed point, accessing memory takes more than accessing registers etc.
   - **CPU clock cycles** is the number of CPU clock cycles
   - Given the above concepts :
     - clock rate=1/clock cycle time (1)
     - CPU time = CPU clock cycles x clock cycle time (2)

- CPU time = CPU clock cycles / clock rate , *because of (1) and (2)* (3)
- CPU clock cycles = (instruction/program) x (clock cycles/instruction)= = Instruction count x CPI (4)
- CPU time = Instruction count x CPI x clock cycle time, *because of (2) and (4)* (5)
- CPU time = Instruction count x CPI / clock rate, *because of (3) and (4)* (6)
- (instructions/program) x (clock cycles / instruction) x (seconds/clock cycle) *because of (1) and (2)* (7)

4. Consider that [redacted] MHz and the Program takes 45 million cycles to execute. Wha[redacted] **wer: 45,000,000 * (1 / 1,000,000) sec = $45*10^6$ * ($1/10^6$) sec = $45*10^6$ [redacted]c = $45 *10^0$ sec = 45*1 sec = 45 seconds**

5. A program has 100 instructions from which 25 instructions are loads (each take 3 cycles), 50 instructions are add (each takes 1 cycle) and 25 instructions are branch (each takes 2 cycles). What is the CPI for this benchmark? **Answer: CPI = 3*(25/100) + 1*(50/100) + 2*(25/100) = ((0.25 * 3) + (0.50 * 1) + (0.25 * 2)) = 1.75 cycles per instruction**

6. Assume a program of 1.000.000 instructions and two implementations of the same instruction set architecture (ISA). CPU.A has a clock cycle time of 10 ns. and a CPI of 2.0, while CPU.B has a clock cycle time of 20 ns. and a CPI of 1.2. Which CPU is faster for this program?

   Answer:

   CPU time = Instruction count x CPI x clock cycle time. Thus,
   *CPU.A time = 10^6 * 2.0 * 10 * 10^{-9} = 2 * 10^{6+1-9} seconds = 2 * 10^{-2} sec = 2/100 sec = 0.02 sec*
   *CPU.B time = 10^6 * 1.2 * 20 * 10^{-9} = 1.2 * 2*10 * 10^6 * 10^{-9} seconds = 1.2 * 2 * 10^{7-9} seconds = 2.4 *10^{-2} sec = 2.4/100 = 0.024 sec*
   CPUA is faster 0.024/0.020=1.2 times

7. Performance Metrics
   - **MIPS** : millions of instructions per second
   - **FLOPS** : floating point operations per second

   Consider a CPU of 500MHz and three different classes of instructions: Class A, Class B, and Class C, which require one, two, and three cycles, respectively. The first code uses 5 billions Class A instructions, 1 billion Class B instructions, and 1 billion Class C instructions. The second compiler's code uses 10 billions Class A instructions, 1 billion Class B instructions, and 1 billion Class C instructions. Which sequence will be faster according to MIPS? Which sequence will be faster according to execution time?

   Answer:
   CPU Clock cycles1= (5 x 1 + 1 x 2 + 1 x 3) x 10^9= 10 x 10^9
   CPU Clock cycles2= (10 x 1 + 1 x 2 + 1 x 3) x 10^9= 15 x 10^9
   CPU time1= 10 x 10^9/ 500 x 10^6= 20 seconds (CPU time = CPU clock cycles / clock rate)
   CPU time2= 15 x 10^9/ 500 x 10^6= 30 seconds
   MIPS = instruction count / (execution time x 10^6)
   MIPS1= (5 + 1 + 1) x 10^9/ 20 x 10^6= 350
   MIPS2= (10 + 1 + 1) x 10^9/ 30 x 10^6= 400

8. Why in 32-bit CPUs we can use only up to 4GBytes of RAM memory?

   Answer: In 32-bit CPUs the address bus is 32bit wide. This means that there are 32 digits to address all w and thus the memory consists of 2^{32} words/bytes, i.e., 4Gbytes.

9. If main memo every word is of 4 bytes, how many bits do we need to address any s ?

   ***Answer**: The e is 32 MB, which means 32 * $2^{20}=2^5*2^{20}=2^{25}$. However, each word is four (2^2) bytes, which means that we have $2^{25}/2^2 = 2^{23}$ words. Note that (Mem.size=number.words x word.size). This means that we need $log_2\ 2^{23} = 23*log_2 2 = 23*1 = 23$ bits, to address each word.*

10. Perform the task in slide 38 (week4_a.pdf).

Algebra basics

$a^x * a^y = a^{x+y}$

$a^x / a^y = a^{x-y}$

$1/a^x = a^{-x}$

$log_b\ a^x = x * log_b\ a$

$log_2\ 2 = 1$

$16000 = 1.6 * 10000 = 1.6 * 10^4$