Course Name: CPE 142
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Instructor: Dr
Assignme
Due Date: Sep
Date Submitted:
Name

1. Clearly describe the difference between computer architecture and computer organization. (10 Points)
    - Computer Architecture is usually known as the programmers' view. Instruction set architecture (ISA) is usually associated with computer architecture. In the programmers view there are instruction sets, data, and addressing techniques. Computer Architecture connects the software with the hardware.
    - Computer Organization include RAM, ALU, CPU, all physical hardware and peripheral devices. The hardware takes the instruction sets from the computer architecture and implements them using the hardware.

2. Define CPU execution time and explain how it can be calculated. (10 points)
    - To understand CPU execution time, we first need to understand what a clock cycle is defined as. A clock cycle is the time for one clock period, usually the processor clock, which runs at a constant rate. A clock period is the combination of complete clock cycle and clock rate. With clock rate comes performance which comes down to CPU execution. CPU execution is the time it takes to perform a command, whether it is for a program or the OS. The formula for CPU execution is:

    [CPU execution time for a program = CPU clock cycles for a program * Clock cycle time] →

    [CPU execution time for a program = (CPU clock cycles for a program/Clock rate)]

    You can improve performance by reducing the number of clock cycles required for a program or the length of the clock cycle.
3. Define response time. (5 points)
    - Response time also known as execution time is the total time required for a computer to complete a task, including disk accesses, memory accesses, I/O activities, operating system overhead, CPU execution time, and so on. It is also known as the time taken between the start and completion of a task.

Problem 1.5

Consider three different processors P1, P2, P3 executing the same instruction set. P1 has a 3 GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.2.

Processor	Clock Rate	CPI
P1	3 GHz	1.5
P2	2.5 GHz	1.0
P3	4 GHz	2.2

a) Which processor has the highest performance expressed in instructions per second?

$$\text{Performance} = \frac{\text{Clock Rate}}{\text{CPI}}$$

P1: $\frac{3\times10^9}{1.5} = 2000000000 = 2\times10^9$ instructions per second.

P2: $\frac{2.5\times10^9}{1} = 2500000000 = 2.5\times10^9$ instructions per second

P3: $\frac{4.0\times10^9}{2.2} = 1810000000 = 1.81\times10^9$ instructions per second

The processor with less time performs better, therefore processor P3 has the highest performance in terms of instructions per seconds.

b) If the processors each execute a program in 10 seconds, find the number of instructions.

$$\text{Number of cycles} = \text{time} \times \text{Clock rate}$$

$$\text{Number of instructions} = \frac{\text{number of cycles}}{\text{CPI}}$$

P1: $10 \times (3 \times 10^9) \rightarrow 30 \times 10^9$ number of cycles

$\frac{30 \times 10^9}{1.5} = \boxed{20 \times 10^9 \text{ number of instructions}}$

P2: $10 \times (2.5 \times 10^9) \rightarrow 25 \times 10^9$ number of cycles

$\frac{25 \times 10^9}{1.0} = \boxed{25 \times 10^9 \text{ number of instructions}}$

P3: $10 \times (4 \times 10^9) = 40 \times 10^9$ number of cycles

$\frac{40 \times 10^9}{2.2} = \boxed{18.18 \times 10^9 \text{ number of instructions}}$

c) We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

$$\text{CPU Time} = \frac{(I \times CPI)}{\text{Clock rate}}$$

$t_1 = \frac{70 \times t}{100} = 0.7t$ so CPU time is 7 seconds.

$$CPI = \frac{(120 \times CPI)}{100} = 1.2 \times CPI$$

$$\text{Clock rate} = \frac{(\text{Number of instructions} \times CPI)}{\text{Time}}$$

P1: $CPI = 1.2 \times 1.5 = 1.8$

Number of cycles $= 30 \times 10^9$

Number of instructions $= 20 \times 10^9$

$$\text{Clock Rate} = \frac{[(20 \times 10^9) \times 1.8]}{7} = \boxed{5.14 \text{ GHz}}$$

P2: $CPI = 1.2 \times 1.0 = 1.2$

Number of cycles $= 25 \times 10^9$

Number of instructions $= 25 \times 10^9$

$$\text{Clock Rate} = \frac{[(25 \times 10^9) \times 1.2]}{7} = \boxed{4.28 \text{ GHz}}$$

P3: $CPI = 1.2 \times 2.2 = 2.64$

Number of cycles $= 40 \times 10^9$

Number of instructions $= 18.18 \times 10^9$

Clock Rate $= \dfrac{[(18.18 \times 10^9) \times 2.64]}{7} = \boxed{6.85\,GHz}$

Problem 1.6

Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.

Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?

a) What is the global CPI for each implementation?

	Clk Rate	CPI class A	CPI class B	CPI class C	CPI class D
P1	2.5 GHz	1	2	3	3
P2	3 GHz	2	2	2	2

$$\text{CPU Time} = \sum \frac{(I \times CPI)}{\text{Clock Rate}}$$

P1: $\sum \frac{(10^6 \times [(0.1 \times 1) + (0.2 \times 2) + (0.5 \times 3) + (0.2 \times 3)])}{(2.5 \times 10^9)} = \frac{2.6}{2.5}$ milliseconds $= \boxed{1.04 \text{ ms}}$

P2: $\sum \frac{(10^6 \times [(0.1 \times 2) + (0.2 \times 2) + (0.5 \times 2) + (0.2 \times 2)])}{(3 \times 10^9)} = \frac{2}{3}$ milliseconds $= \boxed{0.67 \text{ ms}}$

* P2 is faster than P1

$$\text{Global CPI} = \frac{\text{CPI time} \times \text{clock rate}}{\text{number of instructions}}$$

P1: $\frac{(1.04 \times 10^{-3})(2.5 \times 10^9)}{10^6} = \boxed{2.6 \text{ (global CPI)}}$

P2: $\frac{(0.67 \times 10^{-3})(3 \times 10^9)}{10^6} = \boxed{2.01 \text{ (global CPI)}}$

b) Find the clock cycles required in both cases.

Number of clock cycles = Global CPI × number of instructions

P1: $2.6 \times 10^6 = \boxed{26 \times 10^5 \text{ clock cycles for P1}}$

P2: $2.01 \times 10^6 = \boxed{20.1 \times 10^5 \text{ clock cycles for P2}}$

Problem 6

C-code

```
for (i=0; i<100; i++){
  a[i] = b[i] - d[i];
}
```

a) MIPS

$t0 = a[i] , $t1=b[i] , $t2 = d[i]

MEMORY LOCATION		MIPS	
00000100	Loop:	add $t5, $t4, $t1	//temp register $t5 = address b[i]
00000104		lw $t6, 0($t5)	//temp register $t6 = b[i]
00000108		add $t5, $t4, $t2	//temp register $t5 = d[i] address
0000010C		lw $t7, 0($t5)	//temp register $t7 = d[i]
00000110		sub $t6, $t6, $t7	//temp register $t6 = b[i] - d[i]
00000114		add $t5, $t4, $t0	//temp register $t5 = address a[i]
00000118		sw $t6, 0($t5)	// a[i] = b[i] - d[i]
0000011C		addi $t4, $t4, 4	// i = i+1
00000120		slti $t5, $t4, 10	// $t5 = 1 if $t4 < 100
00000124		bne $t5, $zero, Loop	//go to Loop if $t4 < 100

b) lw = 5 cycles

R-type, addi, sw, Arithmetic = 4 cycles

beq, bne, j = 3 cycles

lw = 5 × 2 = 10

R-type, addi, sw, other Arithmetic = 4 × 7 = 28

beq, bne, j = 3 × 1 = 3

Total Cycles = 41 clock cycles

c) 1.6 GHz system

$$\text{CPU execution time} = \frac{\text{CPU Clock cycles}}{\text{Clock Rate}} = \frac{41 \text{ cycles}}{1.6 \text{ GHz}} = 25.63 \text{ seconds}$$

CPU execution time = 25.63 seconds