Homework 1 - Digital and Computer Systems Architecture

Problem 1 - Write characteristics of the six different classes of computers. (15 Points)

Personal Computers

- General Purpose with a variety of software
- Cost/Performance tradeoff

Server Computers

- Used for running programs for multiple users
- Network based
- High cap, performance, and reliability
- Ranges from very small to very large

Supercomputers

- Used for complex scientific and engineering calculations
- High performance but lowest fraction of market

Embedded Computers

- Hidden inside everyday objects
- Power/Performance/Cost tradeoff is important

Problem 2 - What are the three levels of program code? Describe each level. (15 Points)

High-Level Language

Level of abstraction that is closer to human language. It is easier to read and write. Additionally, it is ideal for portability and productivity.

Assembly Language

Essentially a human-readable version of machine code. It is a low-level language that is specific to a particular computer architecture.

Hardware Representation

The lowest level. It's the actual binary code that the computer reads and executes. Encoded in the form of 1s and 0s.

Problem 3 - Discuss five components of a computer? Give at least two examples for each component. (10 Points)

User Interface

The part of the computer that allows the user to interact with the computer. Examples include the keyboard and mouse.

Storage

The part of the computer that stores data. Examples include hard drives and SSDs.

Network

The part of the computer that allows it to communicate with other computers. Examples include Ethernet and Wi-Fi.

Problem 4 - State Amdahl's law. (5 Points)

It allows us to calculate the speedup of a program when only a portion of the program is sped up. It is given by the formula:

$$T_{improved} = \frac{T_{affected}}{\text{Improvement Factor}} + T_{unaffected}$$

Where:

- $T_{improved}$ is the improved time (The total time it takes to run the program after the improvement)
- $T_{affected}$ is the affected time (The time it takes to run the portion of the program being sped up before the improvement)
- $T_{unaffected}$ is the unaffected time (The time it takes to run the portion of the program not being sped up before the improvement)

Problem 5 - Consider three different processors P1, P2, and P3 executing the same instruction set. If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions for each processor? (20 Points)

Processor 1

- Clock Rate: 3 GHz
- CPI (Cycles per Instruction): 1.5

$$10 \text{ seconds} * 3E9 \text{ cycles/second} = 3E10 \text{ cycles}$$
$$3E10 \text{ cycles} * \frac{1 \text{ instruction}}{1.5 \text{ cycles}} = 2E10 \text{ instructions}$$

Processor 2

- Clock Rate: 2.5 GHz
- CPI (Cycles per Instruction): 1.0

$$10 \text{ seconds} * 2.5E9 \text{ cycles/second} = 2.5E10 \text{ cycles}$$
$$2.5E10 \text{ cycles} * \frac{1 \text{ instruction}}{1 \text{ cycle}} = 2.5E10 \text{ instructions}$$

Processor 3

- Clock Rate: 4 GHz
- CPI (Cycles per Instruction): 2.2

$$10 \text{ seconds} * 4E9 \text{ cycles/second} = 4E10 \text{ cycles}$$
$$4E10 \text{ cycles} * \frac{1 \text{ instruction}}{2.2 \text{ cycles}} = 1.818E10 \text{ instructions}$$

Problem 6 - Consider two different implementations of the same ISA. The instructions can be divided into classes as follows (Classes A, B, C, D): (35 Points)

Class	A	B	C	D
CPI (P1)	1	2	3	3
CPI (P2)	2	2	2	2

P1 and P2 have clock rate of 2.5 GHZ and 3.0 GHZ, respectively. Given a program of 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.

P1

$$\begin{aligned} \text{CPI}_{\text{avg}} &= (0.1 * 1) + (0.2 * 2) + (0.5 * 3) + (0.2 * 3) \\ &= 2.6 \text{ cycles/instruction} \end{aligned}$$

$$\begin{aligned} \text{Cycles} &= 2.6 \text{ cycles/instruction} * 1E6 \text{ instructions} \\ &= 2.6E6 \text{ cycles} \end{aligned}$$

$$\begin{aligned} \text{Time} &= \frac{2.6E6 \text{ cycles}}{2.5E9 \text{ cycles/second}} \\ &= 1.04E{-}3 \text{ seconds} \end{aligned}$$

P2

$$\begin{aligned}\text{CPI}_{\text{avg}} &= (0.1 * 2) + (0.2 * 2) + (0.5 * 2) + (0.2 * 2) \\ &= 2 \text{ cycles/instruction}\end{aligned}$$

$$\begin{aligned}\text{Cycles} &= 2 \text{ cycles/instruction} * 1E6 \text{ instructions} \\ &= 2E6 \text{ cycles}\end{aligned}$$

$$\begin{aligned}\text{Time} &= \frac{2E6 \text{ cycles}}{3E9 \text{ cycles/second}} \\ &= 6.67E{-}4 \text{ seconds}\end{aligned}$$

Which is faster?

P2 is faster.

What is the average CPI for each implementation?

P1: 2.6 cycles/instruction

P2: 2 cycles/instruction

How many clock cycles for each case?

P1: 2.6E6 cycles

P2: 2E6 cycles