CS330 Architecture and Organization
Assignment Chapter 1

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Problem 1.1 — (2 points) Aside from the smart cell phones used by a billion people, list and describe four other types of computers. (Section 1)

Answer:

1. Desktop
2. Laptop
3. Smart Watch
4. Calculator

Problem 1.3 — (3 points) Describe the steps that transform a program written in a high-level language such as C into a representation that is directly executed by a computer processor. (Section 3)

Answer: 1. A compiler could read the high-level source code and translate the source code into a assembly language.

2. Then, the assembler transforms the assembly language into machine language, which is what a computer understands and executes directly.

Problem 1.4 — Assume a color display using 8 bits for each of the primary colors (red, green, blue) per pixel and a frame size of 1280×1024. (Section 4)

a. (2 points) What is the minimum size in bytes of the frame buffer to store a frame?

Answer: As we all know that

$$1\ byte = 8\ bits$$

So, we have that each color of the pixel is 1 byte. Then, the pixel is:

$$3 \times 1\ bit = 3\ bits$$

Therefore, the minimum size of the frame buffer is:

$$3 \times 1280 \times 1024 = 3932160\ bytes$$

b. (2 points) How long would it take, at a minimum, for the frame to be sent over a 100 Mbits/s network?

Answer:

We have:

$$1\ byte = 8\ bits$$

The size of the frame buffer in bits is:

$$3932160\ bytes \times 8\ bits = 31457280\ bits$$

Therefore, we could calculate the times:

$$\begin{aligned} times &= \frac{size}{speed} \\ &= \frac{31457280 \;\; bits}{100 \;\; Mbits/s} \\ &= \frac{31457280 \;\; bits}{100 \times 10^6 \;\; bits/s} \\ &= \frac{31457280 \;\; bits}{10^8 \;\; bits/s} \\ &= 0.3145728 \;\; s \end{aligned}$$

Problem A — Consider three different processors that implement the same instruction set architecture. Call the implementations P_1, P_2, and P_3:

Processor	**Clock Rate**	**CPI**
P_1	3 GHz	1.5
P_2	2.5 GHz	1.0
P_3	4.0 GHz	2.2

(Section 6)

a. (4 points) Calculate the clock tick time for each processor. Give your answer in picoseconds, rounded to the closest picosecond.

Answer:

For P_1:

$$\begin{aligned} clock \;\; time &= \frac{1}{clock \;\; rate} \\ &= \frac{1}{3 \;\; GHz} \\ &= \frac{1}{3 \times 10^9 \;\; Hz} \\ &= 3.33 \times 10^{-10} \;\; s \\ &= 333.33 \;\; ps \end{aligned}$$

For P_2:

$$\begin{aligned} clock \;\; time &= \frac{1}{clock \;\; rate} \\ &= \frac{1}{2.5 \;\; GHz} \\ &= \frac{1}{2.5 \times 10^9 \;\; Hz} \\ &= 4.0 \times 10^{-10} \;\; s \\ &= 400 \;\; ps \end{aligned}$$

For P_3:

$$\begin{aligned}
clock\ \ time &= \frac{1}{clock\ \ rate} \\
&= \frac{1}{2.5\ \ GHz} \\
&= \frac{1}{4.0 \times 10^9\ \ Hz} \\
&= 2.5 \times 10^{-10}\ \ s \\
&= 250\ \ ps
\end{aligned}$$

b. (2 point) Which processor has the highest performance, if we are interested only in clock cycles per second?

Answer:

P_3, because P_3 has maximum number of clock cycles per second.

c. (3 points) Suppose each processor executes a program for 10 seconds. Calculate the number of clock cycles used. Give your answer rounded to the closest whole number.

Answer: We have the executing time = 10 seconds.

For P_1:

$$\begin{aligned}
Number\ \ of\ \ clock\ \ cycles &= execution\ \ time \times clock\ \ rate \\
&= 10\ \ seconds \times 3 \times 10^9\ \ \frac{cycles}{second} \\
&= 3 \times 10^{10}\ \ cycles
\end{aligned}$$

For P_2:

$$\begin{aligned}
Number\ \ of\ \ clock\ \ cycles &= execution\ \ time \times clock\ \ rate \\
&= 10 \times 2.5 \times 10^9 \\
&= 2.5 \times 10^{10}\ \ cycles
\end{aligned}$$

For P_3:

$$\begin{aligned}
Number\ \ of\ \ clock\ \ cycles &= execution\ \ time \times clock\ \ rate \\
&= 10 \times 4.0 \times 10^9 \\
&= 4.0 \times 10^{10}\ \ cycles
\end{aligned}$$

d. (3 points) Calculate the average number of instructions executed per second for each processor. Which processor has the highest performance, if we are interested only in the average number of instructions executed per second?

Answer:

For P_1:

$$\begin{aligned} Number\ \ of\ \ instructions\ \ per\ \ second &= \frac{clock\ \ rate}{CPI} \\ &= \frac{3 \times 10^9}{1.5} \\ &= 2 \times 10^9\ \ instructions/s \end{aligned}$$

For P_2:

$$\begin{aligned} Number\ \ of\ \ instructions\ \ per\ \ second &= \frac{clock\ \ rate}{CPI} \\ &= \frac{2.5 \times 10^9}{1.0} \\ &= 2.5 \times 10^9\ \ instructions/s \end{aligned}$$

For P_3:

$$\begin{aligned} Number\ \ of\ \ instructions\ \ per\ \ second &= \frac{clock\ \ rate}{CPI} \\ &= \frac{4.0 \times 10^9}{2.2} \\ &= 1.818 \times 10^9\ \ instructions/s \end{aligned}$$

Therefore, P_2 has highest performance.

e. (3 points) If the processors each execute a particular program in 10 seconds, find the number of instructions used by each processor.

Answer:

For P_1:

$$\begin{aligned} Number\ \ of\ \ instructions &= \frac{execution\ \ time \times clock\ \ rate}{CPI} \\ &= \frac{3 \times 10^{10}}{1.5} \\ &= 2 \times 10^{10}\ \ instructions \end{aligned}$$

For P_2:

$$\begin{aligned} Number\ \ of\ \ instructions &= \frac{execution\ \ time \times clock\ \ rate}{CPI} \\ &= \frac{2.5 \times 10^{10}}{1.0} \\ &= 2.5 \times 10^{10}\ \ instructions \end{aligned}$$

For P_3:

$$\begin{aligned} Number\ \ of\ \ instructions &= \frac{execution\ \ time \times clock\ \ rate}{CPI} \\ &= \frac{4.0 \times 10^{10}}{2.2} \\ &= 1.818 \times 10^{10}\ \ instructions \end{aligned}$$

Problem B — Consider two different implementations of an instruction set architecture: P_1 and P_2. The instructions in this ISA can be divided into four different categories: A, B, C, and D. The following table gives the clock rate of each processor, along with the CPIs of the instructions from each class.

	P_1	P_2
Clock Rate	2.5 GHz	3 GHz
CPI for class A instructions	1	2
CPI for class B instructions	2	2
CPI for class C instructions	3	2
CPI for class D instructions	4	2

(Section 6)

When we use the llvm compiler to compile the source code for a particular program, the compiler uses $2.5 \cdot 10^8$ instructions, drawn from the four classes as follows: 10% from A, 20% from B, 50% from C, and 20% from D.

a. (4 points) Calculate the average CPI used during the compilation for both processors?

Answer:

For P_1:

$$\begin{aligned} average\ \ CPI &= 1 \times 10\% + 2 \times 20\% + 3 \times 50\% + 4 \times 20\% \\ &= 0.1 + 0.4 + 1.5 + 0.8 \\ &= 2.8 \end{aligned}$$

For P_2:

$$\begin{aligned} average\ \ CPI &= 2 \times 10\% + 2 \times 20\% + 2 \times 50\% + 2 \times 20\% \\ &= 0.2 + 0.4 + 1.0 + 0.4 \\ &= 2.0 \end{aligned}$$

b. (4 points) How many clock cycles does the compilation take on each processor?

Answer:

For P_1:

$$\begin{aligned} clock\ \ cycles &= CPI \times instruction\ \ count \\ &= 2.8 \times 2.5 \cdot 10^8 \\ &= 7.0 \times 10^8 \end{aligned}$$

For P_2:

$$\begin{aligned} clock\ \ cycles &= CPI \times instruction\ \ count \\ &= 2.0 \times 2.5 \cdot 10^8 \\ &= 5.0 \times 10^8 \end{aligned}$$

c. (4 points) How much time does the compilation take on each processor?

Answer:

For P_1:

$$\begin{aligned} clock\ \ time &= \frac{1}{clock\ \ rate} \\ &= \frac{1}{2.5\ \ GHz} \\ &= \frac{1}{2.5 \times 10^9\ \ Hz} \\ &= 4.0 \times 10^{-10}\ \ s \end{aligned}$$

The taken to compile is:

$$\begin{aligned} times &= clock\ \ cycles \times clock\ \ time \\ &= 7.0 \times 10^8 \times 4.0 \times 10^{-10} \\ &= 0.28\ \ s \end{aligned}$$

For P_2:

$$\begin{aligned} clock\ \ time &= \frac{1}{clock\ \ rate} \\ &= \frac{1}{3.0\ \ GHz} \\ &= \frac{1}{3.0 \times 10^9\ \ Hz} \\ &= 3.33 \times 10^{-10}\ \ s \end{aligned}$$

The taken to compile is:

$$\begin{aligned} times &= clock\ \ cycles \times clock\ \ time \\ &= 5.0 \times 10^8 \times 3.33 \times 10^{-10} \\ &= 0.1665\ \ s \end{aligned}$$

d. (2 points) Which processor is faster on this task?

Answer:

P_2. Because of 0.165s $<$ 0.28s, P_2 use less time than P_1 does.

e. (4 points) Calculate the performance of each processor in terms of compilations per second.

Answer:

For P_1:

$$\begin{aligned} performance\ \ per\ \ second &= \frac{1}{times} \\ &= \frac{1}{0.28\ \ s} \\ &= 3.57\ \ s^{-1} \end{aligned}$$

For P_2:

$$\begin{aligned} performance\ \ per\ \ second &= \frac{1}{times} \\ &= \frac{1}{0.1665\ \ s} \\ &= 6.006\ \ s^{-1} \end{aligned}$$

f. (4 points) Use your answer from e. to determine which processor has the better performance, and then calculate how much faster that processor is than the slower processor.

Answer:

$$\begin{aligned} \frac{P_2\ 's\ \ performance}{P_1's\ \ performance} &= \frac{6.006\ \ s^{-1}}{3.57\ \ s^{-1}} \\ &= 1.68 \end{aligned}$$