This problem set has 6 questions, for a total of 100 points. Answer the questions below and mark your answers in the spaces provided. Please provide details on how your answer was calculated.

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1. 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.

(a) [5 points] What is the minimum size in bytes of the frame buffer to store a frame?

4 bytes = 32 bits. So 1 byte must be 8 bits

each color pixel uses 3 bytes, 1 byte per color "RGB"

Frame: 1280 x 1024

Area = A = W · H = 1280 x 1024 = 1,310,720 Pixels

Size of frame = 3 x 1,310,720 = $\boxed{3,932,160 \text{ bytes}}$

(b) [5 points] How long would it take, at a minimum, for the frame to be sent over a 100 Mbit/s network?

Looking back at the table from slides → 1 mbit/s = 10^6 bit/s

So Answering the question 100 Mbit/s = 100×10^6 bit/s

= 10^8 bit/s

size of frame = 3,932,160 x 8 = 31,457,280 bit

After looking up equation for time => time = $\frac{\text{size}}{\text{speed}}$

$= \frac{31,457,280 \text{ bits}}{10^8 \text{ bit/s}}$

= 0.3145728 s

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

(a) [6 points] Which processor has the highest performance expressed in instructions per second? = IPS

$CPU_{time} = \frac{\text{instruction count} \times CPI}{\text{clock rate}}$ ~~. clock rate~~

$\frac{\text{clock rate} \cdot CPU_{time}}{CPI} = \text{instruction count}$ ~~X CPI~~

$\frac{\text{clock rate} \cdot CPU_{time}}{CPI} = IC$

$\frac{\text{clock rate}}{CPI} \cdot \frac{CPU\ time}{1} = IC$

$\frac{\text{instructions}}{CPU\ time} = \frac{\text{clock rate}}{CPI}$

P_2 has the highest performance in instructions per second

$1\ GHz = 10^9\ Hz$

$IPS_1 = \frac{3\ GHz}{1.5} = 2 \times 10^9$

$IPS_2 = \frac{2.5\ GHz}{1} = 2.5 \times 10^9$

$IPS_3 = \frac{4\ GHz}{2.2} = 1.82 \times 10^9$

(b) [6 points] If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.

CPU time = 10s, $1\ GHz = 10^9\ Hz$

From Problem A I know that instructions = IPS × CPU time,

slides → clock cycles = CPU time × clock rate

Processor 1: $\text{instructions}_1 = 2 \times 10^9 \times 10 = 2 \times 10^{10}$

$\text{clock cycles}_1 = 10 \times 3\ GHz = 10 \times 3 \times 10^9 = 3 \times 10^{10}$

Processor 2: $\text{instructions}_2 = 2.5 \times 10^9 \times 10 = 2.5 \times 10^{10}$

$\text{clock cycles}_2 = 10 \times 2.5\ GHz = 10 \times 2.5 \times 10^9 = 2.5 \times 10^{10}$

Processor 3: $\text{instructions}_3 = 1.82 \times 10^9 \times 10 = 1.82 \times 10^{10}$

$\text{clock cycles}_3 = 10 \times 4\ GHz = 10 \times 4 \times 10^9 = 4 \times 10^{10}$

(c) [6 points] 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?

Just moving variables around!

exec time = CPU time = $\frac{\text{instructions} \times CPI}{\text{clock rate}}$

= exe-time (new) = 0.7 exec-time (old)

same goes for the instructions

we know that the number the program takes to execute is 10 seconds 30% of 10 seconds is 7 0.7

So that means that new CPI $\rightarrow \frac{CPI(new)}{\text{new clock rate}} = \frac{0.7 \cdot CPI(old)}{\text{old clock rate}}$

$CPI(new) = 1.2\ CPI$

$\frac{1.2}{\text{new clock-rate}} = \frac{0.7}{\text{old...}}$ $= \frac{1.2}{0.7} \times$ old clock rate $= 1.71 \times$ old clock rate

Clock rate must increase by 71% to get time down (reduced)

3. 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 2.5GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3GHz 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.

(a) [6 points] What is the global CPI for each implementation?

$CPI = \frac{\text{clock cycle}}{\text{Instruction Count}}$

Came to find out that $1.0E6 = 10^6 = 1{,}000{,}000 = \sum_{n=1}^{n} (CPI \times \frac{\text{instruction count}}{\text{instruction count}})$

$10^6 \times 10\%$
$10^6 \times .10 = 10^5 = 100{,}000$
$10^6 \times 20\% = 2 \times 10^5$
$10^6 \times 50\% = 5 \times 10^5$
$10^6 \times 20\% = 2 \times 10^5$

P_1 clock cycle: $(1 \times 10^5) + (\overset{CP_1}{2} \times 2 \times 10^5) + (3 + 5 \times 10^5) + (3 \times 2 \times 10^5)$
$= 2.6 \times 10^6$

P_2 clock cycle: $(2 \times 10^5) + (2 \times 2 \times 10^5) + (2 \times 5 \times 10^5) + (2 \times 2 \times 10^5)$
$= 2 \times 10^6$

$CPI = \frac{\text{clock cycles}}{\#\text{ of instructions}}$

$P_1 \rightarrow CPI = \frac{2.6 \times 10^6}{10^6} = 2.6$

$P_2 \rightarrow CPI = \frac{2 \times 10^6}{10^6} = 2$

(b) [6 points] Find the clock cycles required in both cases.

According to my previous work from 3a,
I calculated ~~CPU~~ clock cycles for
Both Cases.
P_1 clock cycle required is 2.6×10^6 and
P_2 clock cycle required is 2×10^6

4. Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5s.

(a) [6 points] Find the average CPI for each program given that the processor has a clock cycle time of 1ns.

$$\text{CPU time} = \frac{IC \times CPI \times \text{cycle time}}{IC \quad \text{cycle time}}$$

$1ns = 10^{-9}s$

$$CPI = \frac{\text{CPU time}}{IC \times \text{cycle time}}$$

$$A \rightarrow CPI = \frac{1.1s}{10^9 \times 10^{-9}s} = 1.1$$

$$B \rightarrow CPI = \frac{1.5s}{1.2 \times 10^9 \times 10^{-9}s} = 1.25$$

(b) [6 points] Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?

$$CPU = \frac{IC \times CPI}{\text{clock rate}}$$

both A and B have buses the same so that means that it's exucution time is the same.

$$A \text{ clock rate} = \frac{IC_A \times CPI_A}{IC_B \times CPI_B} \times \text{clock rate}_B = \frac{10^9 \times 1.1}{1.2 \times 10^9 \times 1.25} \times cr_B$$

A clock rate = 0.73 clock rate B

73%

P_1 is about 27% slower than P_2

(c) [6 points] A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using the new compiler versus using compiler A or B on the original processor?

or

$$CPU_C = IC_A \times CPI \times \text{Cycle time} = 6 \times 10^8 \times 1.1 \times 10^{-9}_s = 0.66_s$$

$\frac{\text{CPU time A}}{\text{CPU time}}$

$$\frac{C}{A} = \frac{1.1_s}{0.66_s} = 1.67$$

$$\frac{C}{B} = \frac{1.5_s}{0.66_s} = 2.27$$

C is about 1.67 times faster than A, and about 2.27 times faster than B

5. The results of the SPEC CPU2006 bzip2 benchmark running on an AMD Barcelona has an instruction count of 2.389E12, an execution time of 750s, and a reference time of 9650s.

(a) [6 points] Find the CPI if the clock cycle time is 0.333ns.

execution time = clock cylles X cycle time

exec-time = 750s
cycle time = 0.333 ns
convert ns
= 0.333×10^{-9} s

Based on equation and given variables, isolate the variable I am solving for → "clock cycles"

clock cycles = $\frac{750}{0.333 \times 10^{-9}} = 2.25 \times 10^{12}$

recall:
1 ns = 10^{-9} s

clock cycles = # of instructions X CPI

CPI = $\frac{CC}{\# \text{ of}} = \frac{2.25 \times 10^{12}}{2.389 \times 10^{12}} = \boxed{0.94}$ ← CPI

(b) [6 points] Find the SPECratio. = SPECration = SPECr ←

SPEC ratio = $\frac{\text{Reference time}}{\text{exec time}} = \frac{9650 \leftarrow \text{Given}}{750 \leftarrow \text{Given}} = 12.87$

(c) [6 points] Suppose that we are developing a new version of the AMD Barcelona processor with a 4GHz clock rate. We have added some additional instructions to the instruction set in such a way that the number of instructions has been reduced by 15%. The execution time is reduced to 700s and the new SPECratio is 13.7. Find the new CPI.

Given

cycle time = $\frac{1}{4GHz} = 0.25 \times 10^{-9}$ s

$1\ GHz = 10^{-9}$ s

exe-time = 700

exec-time = clock cycles X cycle time

clock cycles = $\frac{\text{exec-time}}{\text{cycle time}} = \frac{700}{0.25 \times 10^{-9}} = 2.8 \times 10^{12}$

now I can find CPI, since I have clock cycles and number of instructions

$CPI = \frac{2.8 \times 10^{12}}{2.03 \times 10^{12}} = 1.38$

↑ instructions reduced by 15%

(d) [6 points] For a second benchmark, libquantum, assume an execution time of 960ns, CPI of 1.61, and clock rate of 3GHz. If the execution time is reduced by an additional 10% without affecting to the CPI and with a clock rate of 4GHz, determine the number of instructions.

Given

exec-time = 0.9×960 ns = 864×10^{-9} s

CPI = 1.61

clock rate = 4×10^9

CPI = $\frac{\text{exec-time} \times \text{clockrate}}{\#\text{ of instruction}}$ ← solve for

# of instructions = $\frac{\text{exec-time} \times \text{clock rate}}{CPI}$

$= \frac{864 \times 10^{-9} \times 4 \times 10^{9}}{1.61}$

$= \boxed{2147}$

6. Section 1.11 (textbook) cites as a pitfall the utilization of a subset of the performance equation as a performance metric. To illustrate this, consider two processors. P1 has a clock rate of 4GHz, average CPI of 0.9, and requires the execution of 5.0E9 instructions. P2 has a clock rate of 3GHz, an average of CPI of 0.75, and requires the execution of 1.0E9 instructions.

   (a) [6 points] One usual fallacy is to consider the computer with the largest clock rate as having the largest performance. Check if this is true for P1 and P2.

Given

$P_1 \rightarrow cr = 4GHz = 4\times10^{-9}$

Average CPI = 0.9

exc-time = 5.0×10^{9}

$P_2 \rightarrow cr = 3GHz = 3\times10^{-9}$

average CPI = 0.75

exec-time = 1.0×10^{9}

$$P_{1-2} = \frac{IC \times CPI}{\text{Clock rate}}$$

$$P_1 = \frac{5\times10^9 \times 0.9}{4\times10^9} = 1.125_s$$

$$P_2 = \frac{10^9 \times 0.75}{3\times10^9} = 0.25_s$$

clock rate (P_1) > clock rate (P_2), Performance (P_1) < P_2

   (b) [6 points] Another fallacy is to consider that the processor executing with the largest number of instructions will need a larger CPU time. Consider that processor P1 is executing a sequence of 1.0E9 instructions and that the CPI of processors P1 and P2 do not change, determine the number of instructions that P2 can execute in the same time that P1 needs to execute 1.0E9 instructions.

$$P_1 \text{ CPU time} = \frac{10^9 \times 0.9}{4\,GHz} = \frac{0.9\times10^9}{4\times10^9 Hz} = 0.225_s$$

$$P_2 \rightarrow \frac{\#\text{ of instructions} \times 0.75}{3\,GHz} = 0.225_s$$

$$\#\text{ of instructions} = \frac{0.225\times3\times10^9}{0.75} = 9\times10^8$$

It is clearly that P_1 can process more instructions than P_2 and most importanly at the same period time

(c) [6 points] A common fallacy is to use MIPS (millions of instructions per second) to compare the performance of two different processors, and consider that the processor with the largest MIPS has the largest performance. Check if this is true for P1 and P2.

$$MIPS = \frac{\text{clock rate}}{CPI \times 10^6}$$

$$P_1 = \frac{4\,GHz}{0.9 \times 10^6} = \frac{4 \times 10^9\,Hz}{0.9 \times 10^6} = 4444$$

$$P_2 = \frac{3\,GHz}{0.75 \times 10^6} = \frac{3 \times 10^9\,Hz}{0.75 \times 10^6} = 4000$$

P_1 has bigger MIPS