CSE 2312: Computer Organization & Assembly Language Programming Spring 2018

Homework #1

Student Name: _____

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Directions: Answer the questions on the following pages. Show all applicable steps for any problems requiring the use of formulas or calculations. Submit your completed assignment electronically as a single PDF document with this completed coversheet as the first page and your name written at the top of all additional pages. You may also submit the document in person before the deadline, in which case this coversheet must be completed and stapled to your solution pages.

1. Consider three processors (P1, P2, P3), each with the same instruction set. P1 has a 1.5 GHz clock rate and a CPI of 2.0. P2 has a 2.0 GHz clock rate and a CPI of 2.5. P3 has a 2.5 GHz clock rate and a CPI of 4.0.

a) Compute the instructions per second for each processor.

b) For each processor executing a different program in 10 seconds, compute the number of cycles and the number of instructions that were performed.

c) For each processor executing the programs in part b, the CPI is increased by 20%. We now wish to reduce the execution time by 30%. What should the new clock rate be for each processor?

2. Consider two processors (P1 and P2) with different implementations of the same ISA. In this ISA, we can classify each instruction into one of 4 classes (A, B, C, D) according to their CPI (in other words, some instructions require more cycles than others). P1 has a clock rate of 3.5 GHz and CPIs of (A=1, B=3, C=3, D=2), while P2 has a clock rate of 2.0 GHz and CPIs of (A=2, B=3, C=3, D=2).

Now consider a program consisting of 1,000,000 instructions with the following distribution (A=10%, B=30%, C=40%, D=20%)

a) What is the global CPI for each implementation?

b) How many clock cycles are required to fully execute the program on P1 and P2?

c) How long, in seconds, does it take each processor to fully execute the program?

3. Consider 2 processors (P1 and P2). P1 has a clock rate of 2.5 GHz, a voltage of 1.25 V, and a dynamic power expenditure of 85 Watts. P2 has a clock rate 3.5 GHz, a voltage of 1.0 V, and a dynamic power expenditure of 80 Watts.

a) What is the capacitive load for each processor?

b) Suppose we are able to lower the capacitive load of both processors by 20%, while also decreasing the voltage by 15%. What is the affect on dynamic power for each processor?

4. Assume a 20 cm diameter wafer has a cost of $500, contains 80 dies, and has 0.04 defects/cm^2.

a) Compute the yield for this wafer.

b) Compute the cost per die for this wafer.

c) If the number of dies per wafer is increased by 10% and the defects per area unit increases by 15%, find the die area and yield.

5. Consider a processor executing a program consisting of 3 different instructions classes (A, B, C), each with the same CPI, and with distributions A=40%, B=40%, C=20%. As currently implemented, the program executes in 500 milliseconds. How long would it take for the program to fully execute if we modify the processor such that the speed of class B instructions is doubled (i.e., class B instructions take half as long after the improvement)? In this scenario, how much faster is the improved processor relative to the original?

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1.a) $IPS = \frac{\text{clock rate}}{CPI} \rightarrow \frac{\text{cycles/sec}}{\text{cycles/Instruction}} = \frac{\text{Instruction}}{\text{sec}}$

$IPS_{p1} = \frac{1.5\,GHz}{2.0} = \frac{1.5 \times 10^9\,Hz}{2.0} =$ **750,000,000 IPS or 750 MIPS**

3pts

$IPS_{p2} = \frac{2.0\,GHz}{2.5} = \frac{2.0 \times 10^9\,Hz}{2.5} =$ **800,000,000 IPS or 800 MIPS**

3pts

$IPS_{p3} = \frac{2.5\,GHz}{4.0} = \frac{2.5 \times 10^9\,Hz}{4.0} =$ **625,000,000 IPS or 625 MIPS**

3pts

b) # of cycles = CPU Time x cycles/sec

(# of cycles = clock cycles ex time = CPU Time)

$\#\text{ of cycles}_{p1} = (10\,s)(1.5\,GHz) = (10)(1.5 \times 10^9\,Hz) =$ **15,000,000,000 cycles or 15×10^{10} cycles**

3pts

$\#\text{ of cycles}_{p2} = (10\,s)(2.0\,GHz) = (10)(2 \times 10^9\,Hz) =$ **20,000,000,000 cycles or 2.0×10^{10} cycles**

3pts

$\#\text{ of cycles}_{p3} = (10\,s)(2.5\,GHz) =$ **25,000,000,000 cycles or 2.5×10^{10} cycles**

3pts

instructions = CPU Time x IPS

$\#\text{ instructions}_A = (10\,s)(750,000,000) =$ **7,500,000,000 instructions**

3pts

$\#\text{ instructions}_B = (10\,s)(800,000,000) =$ **8,000,000,000 instructions**

3pts

$\#\text{ instructions}_C = (10\,s)(625,000,000) =$ **6,250,000,000 instructions**

3pts

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1c) Ex Time new = 0.7 Ex Time old
CPU Time new = 0.7 CPU Time old
CPI new = CPI old (1.2)

$$\text{Clock Rate new} = \frac{\text{CPI new} \cdot \text{Instructions}}{\text{CPU Time new}}$$

3pts

$$\text{Clock Rate new}_{P1} = \frac{(1.2)(2.0)(7,500,000,000)}{(0.7)(10\text{ s})} = \boxed{2,571,428,571\text{ Hz} \text{ or } 2.57\text{ GHz}}$$

3pts

$$\text{Clock Rate new}_{P2} = \frac{(1.2)(2.5)(8,000,000,000)}{(0.7)(10\text{ s})} = \boxed{3,428,571,428\text{ Hz} \text{ or } 3.43\text{ GHz}}$$

3pts

$$\text{Clock Rate new}_{P3} = \frac{(1.2)(4.0)(6,250,000,000)}{(0.7)(10\text{ s})} = \boxed{4,285,714,285\text{ Hz} \text{ or } 4.29\text{ GHz}}$$

2.3) P_1 clock Rate = 3.5 GHz P_2 Clock Rate = 2.0 GHz

	A	B	C	D
CPI$_1$	1	3	3	2
CPI$_2$	2	3	3	2
# of instruct.	100K (10%)	300K (30%)	400K (40%)	200K (20%)

$CPI_A = (1)(0.1) + (3)(.3) + (3)(.4) + (2)(0.2) = \boxed{2.6}$ 3pts

$CPI_B = (2)(0.1) + (3)(.3) + (3)(.4) + 2(0.2) = \boxed{2.7}$ 3pts

b) # of cycles = CPI × Instructions

$\#\text{ of cycles}_A = (2.6)(1{,}000{,}000) = \boxed{2{,}600{,}000}$ 3pts

$\#\text{ of cycles}_B = (2.7)(1{,}000{,}000) = \boxed{2{,}700{,}000}$ 3pts

c) $\text{CPU Time} = \dfrac{(\#\text{ of instructions})(CPI)}{\text{cycles/sec}}$

$\text{CPU Time}_A = \dfrac{(1{,}000{,}000)(2.6)}{3.5\text{GHz}} = \boxed{0.000743 \text{ seconds}}$ 3pts

$\text{CPU Time}_B = \dfrac{(1{,}000{,}000)(2.7)}{2.0\text{GHz}} = \boxed{0.00135 \text{ seconds}}$ 3pts

3a) $P = C_L \times V^2 \times f \qquad C_L = \frac{P}{V^2 f}$

$C_{L_1} = \frac{85}{(1.25)^2(2.5\times10^9)} = \boxed{2.176\times10^{-8}\ V}$ 5pts

$C_{L_2} = \frac{80}{(1.0)^2(3.5\times10^9)} = \boxed{2.286\times10^{-8}\ V}$ 5pts

b) $P_1 = (0.8)(2.176\times10^{-8})((0.85)(1.25))^2(2.5\times10^9)$

$= \boxed{49.13\ \text{Watts}}$ 5pts

$P_2 = (0.8)(2.286\times10^{-8})((0.85)(1.0))^2(3.5\times10^9)$

$= \boxed{46.25\ \text{Watts}}$ 5pts

4a) $$\text{Yield} = \frac{1}{(1+(\text{Defects per area} \times \text{Die area}/2))^2}$$

$$\text{die area} = \pi r^2 / (\text{dies/wafer})$$
$$= \frac{3.14(10\text{cm})^2}{80}$$
$$= 3.925\text{cm}^2$$

$$\text{Yield} = \frac{1}{(1+(0.04 \times 3.925/2))^2} = \boxed{0.8597 \text{ or } 85.97\%}$$ 5pts

b) $$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{Yield}}$$
$$= \frac{500}{80 \times 0.8597} = \boxed{\$7.27}$$ 5pts

c) $$\text{die area} = \frac{(3.14)(10)^2}{(1.1)(80)} = \boxed{3.568\text{cm}^2}$$ 3pts

$$\text{Yield} = \frac{1}{(1+((1.15)(0.04) \times 3.568/2))^2} = \boxed{0.8541 \text{ or } 85.41\%}$$ 3pts

5. $CPU\ Time_A = (0.4)(0.5) = 0.2$ seconds
$CPU\ Time_B = (0.4)(0.5) = 0.2$ seconds
$CPU\ Time_C = (0.2)(0.5) = 0.1$ seconds

$CPU\ Time_{new} = 0.2 + 0.2/2 + 0.1 =$ **0.4 seconds**

5pts

$$\frac{Performance_{New}}{Performance_{old}} = \frac{CPU\ Time_{new}}{CPU\ Time_{old}} = \frac{0.5}{0.4} =$$ **1.25 times faster**

5pts