UNIVERSITY OF TEXAS ARLINGTON

CSE 2312: Computer Organization & Assembly Language Programming
Summer 2015

Homework #1

Student Name: SOLUTIONS

Student ID: ______________________

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 a display with *1080p* resolution and *True Color* color depth.

   a) What is the minimum size, in bits, of an uncompressed frame buffer storing a single frame?

   b) Suppose this uncompressed frame is transferred over a *Gigabit Ethernet* connection. What is the minimum amount of time, in seconds, to completed the transfer?

   HINT: use Wikipedia to find specifications for terms in italics.

2. Consider three processors (P1, P2, P3), each with 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 a CPI of 2.2.

   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?

3. 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 2.5 GHz and CPIs of (A=1, B=2, C=3, D=3), while P2 has a clock rate of 3 GHz and CPIs of (A=2, B=2, C=2, D=2).

Now consider a program consisting of 1,000,000 instructions with the following distribution (A=10%, B=20%, C=50%, 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?

4. Consider 2 processors (P1 and P2). P1 has a clock rate of 4.0 GHz, a voltage of 1.25 V, and a dynamic power expenditure of 90 Watts. P2 has a clock rate 3.0 GHz, a voltage of 1.0 V, and a dynamic power expenditure of 50 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?

5. Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 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.

6. Consider a processor executing a program consisting of 3 different instructions classes (A, B, C) with distributions (A=45%, B=30%, C=25%). As currently implemented, the program executes in 10 seconds. How long would it take for the program to fully execute if we double the speed of class B instructions (i.e., class B instructions take half as long after the improvement)?

1) a) 1080p → 1920 × 1080 pixels

True Color → 24 bits/pixel (8 bits each for R, G, B channels)

$1920 \times 1080 \times 24 = \boxed{49{,}766{,}400 \text{ bits/frame}}$

b) Gigabit Ethernet → 1,000,000,000 bits/second

$$\frac{49{,}766{,}400}{1{,}000{,}000{,}000} = \boxed{0.497664 \text{ seconds}}$$

2) a) $\text{Instructions/sec} = \dfrac{\text{Clock Rate}}{\text{CPI}}$

$$IPS_{P1} = \frac{3 \times 10^9 \text{ Hz}}{1.5} = 2 \times 10^9 \text{ I/s} = \boxed{2{,}000{,}000{,}000 \text{ I/s}}$$

$$IPS_{P2} = \frac{2.5 \times 10^9 \text{ Hz}}{1.0} = 2.5 \times 10^9 \text{ I/s} = \boxed{2{,}500{,}000{,}000 \text{ I/s}}$$

$$IPS_{P3} = \frac{4.0 \times 10^9 \text{ Hz}}{2.2} = 1.\overline{81} \times 10^9 \text{ I/s} = \boxed{1{,}818{,}181{,}818 \text{ I/s}}$$

b) $\#\text{Cycles} = (\text{Clock Rate}) \times (\text{Time})$

$\#\text{Instructions} = (\text{Instructions/Second}) \times (\text{Time})$

$\#\text{Cycles}_{P1} = (3.0 \times 10^9 \text{ Hz})(10s) = \boxed{30{,}000{,}000{,}000 \text{ Cycles}}$

$\#\text{Instructions}_{P1} = (2 \times 10^9)(10s) = \boxed{20{,}000{,}000{,}000 \text{ Instructions}}$

$\#\text{Cycles}_{P2} = (2.5 \times 10^9 \text{ Hz})(10s) = \boxed{25{,}000{,}000{,}000 \text{ Cycles}}$

$\#\text{Instructions}_{P2} = (2.5 \times 10^9)(10s) = \boxed{25{,}000{,}000{,}000 \text{ Instructions}}$

$\#\text{Cycles}_{P3} = (4.0 \times 10^9 \text{ Hz})(10s) = \boxed{40{,}000{,}000{,}000 \text{ Cycles}}$

$\#\text{Instructions}_{P3} = (1.\overline{81} \times 10^9)(10s) = \boxed{18{,}181{,}818{,}181 \text{ Instructions}}$

c) $\text{Execution Time}_{new} = \text{Execution Time}_{old} \times (1.0 - 0.3)$

$= (0.7)\,\text{Execution Time}_{old}$

$CPI_{New} = CPI_{old} * (1.0 + 0.20)$

$= (1.2)\,CPI_{old}$

$$\text{Clock Rate}_{New} = \frac{CPI_{New} * \text{Instructions}}{\text{Execution Time}_{New}}$$

$$= \frac{(1.2)(CPI_{old}) * \text{Instructions}}{(0.7) * \text{Execution Time}_{old}}$$

$$\text{Clock Rate}_{New,\,P1} = \frac{(1.2)(1.5)(20{,}000{,}000{,}000)}{(0.7)(10s)} = \boxed{5.14 \text{ GHz}}$$

$$\text{Clock Rate}_{New,\,P2} = \frac{(1.2)(1.0)(25{,}000{,}000{,}000)}{(0.7)(10s)} = \boxed{4.29 \text{ GHz}}$$

$$\text{Clock Rate}_{New,\,P3} = \frac{(1.2)(2.2)(18{,}181{,}818{,}181)}{(0.7)(10s)} = \boxed{6.86 \text{ GHz}}$$

(3) a) $CPI_{Global} = \dfrac{\#\text{ cycles}}{\#\text{ instructions}}$

$$\#\text{ cycles}_{P1} = (1)(0.10)(1{,}000{,}000) + (2)(0.20)(1{,}000{,}000) + (3)(0.50)(1{,}000{,}000) + (3)(0.20)(1{,}000{,}000)$$
$$= 100{,}000 + 400{,}000 + 1{,}500{,}000 + 600{,}000$$
$$= \cancel{2{,}520{,}000}\ 2{,}600{,}000$$

$$\#\text{ cycles}_{P2} = (2)(0.10)(1{,}000{,}000) + (2)(0.20)(1{,}000{,}000) + (2)(0.50)(1{,}000{,}000) + (2)(0.20)(1{,}000{,}000)$$
$$= (2)(1{,}000{,}000)(0.1 + 0.2 + 0.5 + 0.2)$$
$$= 2{,}000{,}000$$

$$CPI_{Global,\,P1} = \frac{2{,}600{,}000}{1{,}000{,}000}$$
$$= \boxed{2.6}$$

$$CPI_{Global,\,P2} = \frac{2{,}000{,}000}{1{,}000{,}000}$$
$$= \boxed{2}$$

b) $\#\text{ cycles}_{P1} = \boxed{2{,}600{,}000}$ (solved above)

$\#\text{ cycles}_{P2} = \boxed{2{,}000{,}000}$ (solved above)

c) $\text{execution time} = \dfrac{\#\text{ instructions} \times CPI}{\text{clock rate}}$

$$\text{execution time}_{P1} = \frac{(1{,}000{,}000)(2.6)}{2.5 \times 10^9}$$
$$= \cancel{\boxed{0.0026\text{ seconds}}}\ \boxed{0.00104\text{ seconds}}$$

$$\text{execution time}_{P2} = \frac{(1{,}000{,}000)(2.0)}{3.0 \times 10^9}$$
$$= \boxed{0.00067\text{ seconds}}$$

(4) Power $= \frac{1}{2}(\text{Capacitive Load}) \times (\text{Voltage})^2 \times \text{Frequency}$

a) $CL = \frac{2P}{V^2F}$

$CL_{P1} = \frac{2(90 \text{ watts})}{(1.25v)^2(4.0 \times 10^9 Hz)} = \frac{180}{6,250,000,000}$

$= \boxed{0.0000000288}$

$CL_{P2} = \frac{2(50 \text{ watts})}{(1.0v)^2(3.0 \times 10^9 Hz)} = \frac{100}{3,000,000,000}$

$= \boxed{0.0000000333}$

b) $\text{Power}_{P1} = \frac{1}{2}(0.0000000288)(0.80) \times [(1.25v)(0.85)]^2 \times (4.0 \times 10^9 Hz)$

$= \boxed{48.96 \text{ watts}}$

$\text{Power}_{P2} = \frac{1}{2}(0.0000000333)(0.80) \times [(1.0v)(0.85)]^2 \times (3.0 \times 10^9 Hz)$

$= \boxed{28.8711 \text{ watts}}$

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

$\text{Die Area} = \frac{\pi r^2}{\text{dies per wafer}} = \frac{(3.14)(\frac{15cm}{2})^2}{84}$

$= 2.103 \text{ cm}^2$

$= \frac{1}{(1 + (0.020 \times \frac{2.103 \text{ cm}^2}{2}))^2}$

$= \boxed{0.959}$

b) $\text{Cost per Die} = \frac{\text{Cost per Wafer}}{\text{Dies per wafer} \times \text{Yield}}$

$= \frac{12}{(84)(0.959)}$

$= \boxed{0.1489}$

c) $\text{Yield} = \frac{1}{(1 + ((1.15)(0.020) \times \frac{1.9115}{2}))^2}$

$= \boxed{0.957}$

$\text{Die Area} = \frac{(3.14)(\frac{15cm}{2})^2}{(1.10)(84)} = \boxed{1.9115}$

⑥ $\text{Execution Time}_A = (0.45)(10s) = 4.5s$

$\text{Execution Time}_B = (0.30)(10s) = 3s$

$\text{Execution Time}_C = (0.25)(10s) = 2.5s$

Amdahl's Law

$$\text{Exec. Time after improvement} = \frac{\text{Exec. Time affected by improvement}}{\text{Amount of improvement}} + \text{Exec. time unaffec}$$

$$= \frac{3.0s}{2} + [(4.5s) + (2.5s)]$$

$$= \boxed{8.5 \text{ seconds}}$$