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Homework 1

1.5 a) Which processor has the highest performance expressed in instructions per second?

Performance = $\frac{Clock\ Rate}{CPI}$

P1:

Performance of P1 = $\frac{3\times 10^9}{1.5} = 2 \times 10^9$ instructions per second

P2:

Performance of P2 = $\frac{2.5\times 10^9}{1.0} = 2.5 \times 10^9$ instructions per second

P3:

Performance of P3 = $\frac{4\times 10^9}{2.2} = 1.818 \times 10^9$ instructions per second

Since less is better in this case, processor 3 is the better one as the time it takes is smaller than the rest. Processor 3 has the highest performance expressed in instructions per second.

b) If the processers each execute a program in 10 seconds, find the number of cycles and the number of instructions.

Number of cycles = $Time\ \times\ Clock\ Rate$

Number of instructions = $\frac{Number\ of\ Cycles}{CPI}$

P1:

Number of cycles = $10 \times (3 \times 10^9) = 3 \times 10^{10}$ cycles

Number of instructions = $\frac{3\times 10^{10}}{1.5} = 2 \times 10^{10}$ instructions

P2:

Number of cycles = $10 \times (2.5 \times 10^9) = 2.5 \times 10^{10}$ cycles

Number of instructions = $\frac{2.5\times 10^{10}}{1} = 2.5 \times 10^{10}$ instructions

P3:

Number of cycles = $10 \times (4 \times 10^9) = 4 \times 10^{10}$ cycles

Number of instructions = $\frac{4\times 10^{10}}{2.2} = 1.818 \times 10^{10}$ instructions

c) 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?

10 s. gets converted to 7 s. as a result of the 30% time reduction

The new CPI's will be $1.2 \times CPI$

Clock Rate = $\frac{Number\ of\ Instructions\ \times CPI}{Time}$

P1:

New CPI of P1 = $1.2 \times 1.5 = 1.8$

New Clock Rate = $\frac{2\times10^{10}\times1.8}{7}$ = 5.14 GHz

P2:

New CPI of P2 = $1.2\ \times\ 1$ = 1.2

New Clock Rate = $\frac{2.5\times10^{10}\times1.2}{7}$ = 4.28 GHz

P3:

New CPI of P3 = $1.2\ \times\ 2.2$ = 2.64

New Clock Rate = $\frac{1.818\times10^{10}\times2.64}{7}$ = 6.85 GHz

1.6 a) What is the global CPI for each implementation?

Global CPI = $\frac{CPI\ Time \times Clock\ Rate}{Number\ of\ Instructions}$

CPU Time = $\sum\frac{(Number\ of\ Instructions \times CPI)}{Clock\ Rate}$

P1:

P1 CPU Time = $\frac{1.0E6\times[(0.1\times1)+(0.2\times2)+(0.5\times3)+(0.2\times3)]}{2.5\times10^{9}}$ = .00104 s.

P1 Global CPI = $\frac{.00104\times2.5\times10^{9}}{1.0E6}$ = 2.6

P2:

P2 CPU Time = $\frac{1.0E6\times[(0.1\times2)+(0.2\times2)+(0.5\times2)+(0.2\times2)]}{3\times10^{9}}$ = 6.66×10^{-4} s.

P2 Global CPI = $\frac{6.66\times10^{-4}\times3\times10^{9}}{1.0E6}$ = 2

b) Find the clock cycles required in both cases.

Number of Clock Cycles = $Global\ CPI\ \times\ Number\ of\ Instructions$

Number of Clock Cycles for P1 = 2.6×10^{6}

Number of Clock Cycles for P2 = 2×10^{6}

1.7 a) Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.

CPI = $\frac{CPU\ Execution\ Time}{Number\ of\ Instructions \times Clock\ Cycle\ Time}$

Compiler A Average CPI = $\frac{1.1}{(1.0E9)\times(1.0E(-9))}$ = 1.1

Compiler B Average CPI = $\frac{1.5}{(1.2E9)\times(1.0E(-9))}$ = 1.25

b) 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?

Execution time of A = $Number\ of\ Instructions\ \times\ Average\ CPI\ \times\ Clock\ Cycle\ Time\ of\ A$

= $1.1E9\times Clock\ Cycle\ Time\ of\ A$

Execution time of B = $Number\ of\ Instructions\ \times\ Average\ CPI\ \times\ Clock\ Cycle\ Time\ of\ B$

= $1.5E9\ \times\ Clock\ Cycle\ Time\ of\ B$

Set them equal and solve for A to get proportion:

$1.1E9 \times Clock\ Cycle\ Time\ of\ A = 1.5E9 \times Clock\ Cycle\ Time\ of\ B$

$Clock\ Cycle\ Time\ of\ A = 1.36 \times Clock\ Cycle\ Time\ of\ B$

This means that the processor running the A compiler is 1.36 times faster than the processor running the B compiler.

c) 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 this new compiler versus using compiler A or B on the original processor?

Execution Time = $6.0E8 \times 1.1 \times 1E(-9)$ = .66

Speedup of A = $\frac{1.1}{.66}$ = 1.66

Speedup of B = $\frac{1.5}{.66}$ = 2.27

1.8 1.8.1) For each processor find the average capacitive loads.

Capacity Load = $\frac{2 \times Dynamic\ Power}{Voltage^2 \times Frequency}$

Pentium 4 Prescott Capacitive Load = $\frac{2 \times 90}{1.25^2 \times 3.6E9}$ = 3.2E(-8)

Core i5 Ivy Bridge Capacitive Load = $\frac{2 \times 40}{0.9^2 \times 3.4E9}$ = 2.9E(-8)

1.8.2) Find the percentage of the total dissipated power comprised by static power and the ratio of static power to dynamic power for each technology.

Pentium 4 Prescott:

Total Power Dissipated = 100 W

Percentage of Total Dissipated Power = $\frac{10}{100} = .1 \times 100$ = 10%

Ratio of Static and Dynamic Power = $\frac{10}{90} = \frac{1}{9}$

Core i5 Ivy Bridge:

Total Power Dissipated = 70 W

Percentage of Total Dissipated Power = $\frac{30}{70} = .42857 \times 100$ = 42.857%

Ratio of Static and Dynamic Power = $\frac{30}{40} = \frac{3}{4}$

1.8.3) If the total dissipated power is to be reduced by 10%, how much should the voltage be reduced to maintain the same leakage current? Note: power is defined as the product of voltage and current.

New Power = $0.9 \times Old\ Power$

$$\frac{New\ Power}{New\ Voltage} = \frac{Old\ Power}{Old\ Voltage}$$

$$\frac{0.9 \times Old\ Power}{New\ Voltage} = \frac{Old\ Power}{Old\ Voltage}$$

$$\frac{0.9}{New\ Voltage} = \frac{1}{Old\ Voltage}$$

New Voltage = $0.9 \times Old\ Voltage$

Pentium 4 Prescott:

New Voltage = 1.125 V

Core i5 Ivy Bridge:
New Voltage = 0.81 V

1.10 1.10.1) Find the yield of both wafers.

First Wafer:

$A = \pi r^2 = 176.625\ cm^2$

Die Area = $\frac{176.625}{84}$ = 2.102 cm^2

Yield = $\frac{1}{(1+(0.02 \times \frac{2.102}{2})^2} = 0.96\ or\ 96\%$

Second Wafer:

$A = \pi r^2 = 314\ cm^2$

Die Area = $\frac{314}{100}$ = 3.14 cm^2

Yield = $\frac{1}{(1+(0.031 \times \frac{3.14}{2})^2} = 0.91\ or\ 91\%$

1.10.2) Find the cost per die for both wafers.

Cost Per Die = $\frac{Cost\ Per\ Wafer}{Dies\ Per\ Wafer \times Yield}$

First Wafer:

Cost Per Die = $\frac{12}{84 \times 0.96}$ = .1488

Second Wafer:

Cost Per Die = $\frac{15}{100 \times 0.91}$ = .1648

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

First Wafer:

Dies Per Wafer = 1.1×84= 92.4

Die Area = $\frac{176.625}{92.4} = 1.92\ cm^2$

Defects Per Area = 1.15×0.02 = 0.023

Yield = $\frac{1}{(1+(0.023 \times \frac{1.92}{2})^2} = 0.957\ or\ 95.7\%$

Second Wafer:

Dies Per Wafer = 1.1×100 = 110

Die Area = $\frac{314}{110} = 2.854\ cm^2$

Defects Per Area = 1.15×0.031 = 0. 3565

Yield = $\frac{1}{(1+(0.03565 \times \frac{2.854}{2})^2} = 0.905\ or\ 90.5\%$