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Problem 1.1

1.5 <§1.6> Consider three different processors P1, P2, and P3 executing 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 has a CPI of 2.2.

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

P1 3e9 / 1.5 = 2GHz

P2 2.5e9 / 1.0 = 2.5GHz

P3 4.0e9 / 2.2 = 1.8GHz

Answer: P2

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

Instructions

P1 10 * 3e9 / 1.5 = 20e9

P2 10 * 2.5e9 / 1.0 = 25e9

P3 10 * 4.0e9 / 2.2 = 18.1e9

Cycles

P1 20e9 * 1.5 = 30e9

P2 25e9 * 1.0 = 25e9

P3 18.1e9 * 2.2 = 40e9

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?

P1 7 = 20e9 x 1.8 / Clock rate	Clock rate = 5.15GHz
P2 7 = 25e9 x 1.2 / Clock rate	Clock rate = 4.28GHz
P3 7 =18.1e9 x 2.6 / Clock rate	Clock rate = 6.75GHz

Problem 1.2

1.7 [15] <§1.6> 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 1.1 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.
a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.

A 1.1/1.0e9 * 1e-9 = 1.1

B 1.5/1.2e9 * 1e-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?

(1.25 * 1.2e9)/(1.1 * 1.0e9) = 1.36 times faster

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?

1.0 * 0.6 = 0.6

A 1.1e9 / 6.6e8 = 1.67

B 1.5e9 / 6.6e8 = 2.27

Problem 1.3

1.10 Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 defects/cm^2. Assume a 20 cm diameter wafer has a cost of 15, contains 100 dies, and has 0.031 defects/cm^2.
1.10.1 [10] <§1.5> Find the yield for both wafers.

Wafer A Yield = 1 / (1 + (0.020 X 2.10/2))2 = 0.959

Wafer B Yield = 1/ (1 + (0.031 X 3.14/2))2 = 0.909

1.10.2 [5] <§1.5> Find the cost per die for both wafers.

Cost per die A = 12 / (84 * 0.959) = 0.149
Cost per die B = 15 / (100 * 0.909) = 0.165

1.10.3 [5] <§1.5> 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.

A Die Area = 176.7/92.4 = 1.91
Yield =12/ (0.149 * 92.4) = 0.958

B Die Area = 314.2/110 = 2.86
Yield = 15 / (0.165 * 110) = 0.908

1.10.4 [5] <§1.5> Assume a fabrication process improves the yield from 0.92 to 0.95. Find the defects per area unit for each version of the technology given a die area of 200 mm^2.

$$\text{Defects per area}_{0.92} = (1 - (0.92)^{.5}) / ((0.92)^{.5} * 2/2) = 0.043$$

$$\text{Defects per area}_{0.95} = (1 - (0.95)^{.5}) / ((0.95)^{.5} * 2/2) = 0.026$$

Problem 1.4

1.14 Assume a program requires the execution of 50 $\times 10^6$ FP instructions, 110 $\times 10^6$ INT instructions, 80 $\times 10^6$ L/S instructions, and 16 $\times 10^6$ branch instructions. The CPI for each type of instruction is 1, 1, 4, and 2, respectively. Assume that the processor has a 2 GHz clock rate.
1.14.1 [10] <§1.10> By how much must we improve the CPI of FP instructions if we want the program to run two times faster?

Initial clock cycles = 1 * 50e6FP + 1 * 110e6 INT + 4 * 80e6L/S + 2 * 16e6branch = 512e6

CPU time = 512e6 / 2e9 = 0.256s

Desired time = 0.128

Desired clock cycles = 0.128 * 2e9 = 256e6

256e6 = x * 50e6 + 110e6 + 4*80e6 + 2 * 16e6

$X = (256e6 – 462e6) / 50 = -4.12$

Not possible

1.14.2 [10] <§1.10> By how much must we improve the CPI of L/S instructions if we want the program to run two times faster?

Using clock cycles from previous question

Desired clock cycles = 256e6

50 + 110 + 32 = 192 instructions excluding FP

$X = (256 – 192) / 80 = 0.8$

1.14.3 [5] <§1.10> By how much is the execution time of the program improved if the CPI of INT and FP instructions is reduced by 40% and the CPI of L/S and Branch is reduced by 30%?

Clock cycles = 0.6 * 1 * 50e6FP + 0.6 * 1 * 110e6 INT + 0.7 * 4 * 80e6L/S + 0.7 * 2 * 16e6branch

= 30e6 + 66e6 + 224e6 + 22.4e6

= 342.2e6

T_{init} = 0.256s

T_{new} = 342.2e6 / 2e9 = 0.171s