

Introduction to Computer Architecture

Assignment 1 - Solution

Due March 18, 2014

1. [40 = 10 x 4] It costs \$1 billion to build a new fabrication facility. You will be selling a range of chips from that factory, and you need to decide how much capacity to dedicate to each chip. Your Woods chip will be 150 mm² and will make a profit of \$20 per defect-free chip. Your Markon chip will be 250 mm² and will make a profit of \$25 per defect-free chip. Your fabrication facility will be identical to that for the Power5. Each wafer has a 300 mm diameter.

- How much profit do you make on each wafer of Woods chip?
- How much profit do you make on each wafer of Markon chip?
- Which chip should you produce in this facility?
- What is the profit on each new Power5 chip? If your demand is 50,000 Woods chips per month and 25,000 Markon chips per month, and your facility can fabricate 150 wafers a month, how many wafers should you make of each chip?

Solution

$$\text{a. Dies per wafer} = \frac{\pi \times (30/2)^2}{1.5} - \frac{\pi \times 30}{\text{sqrt}(2 \times 1.5)} = 471 - 54.4 = 416$$

$$\text{Yield} = \left(1 + \frac{0.30 \times 1.5}{4.0}\right)^{-4} = 0.65$$

$$\text{Profit} = 416 \times 0.65 \times \$20 = \$5408$$

$$\text{b. Dies per wafer} = \frac{\pi \times (30/2)^2}{2.5} - \frac{\pi \times 30}{\text{sqrt}(2 \times 2.5)} = 283 - 42.1 = 240$$

$$\text{Yield} = \left(1 + \frac{0.30 \times 2.5}{4.0}\right)^{-4} = 0.50$$

$$\text{Profit} = 240 \times 0.50 \times \$25 = \$3000$$

- The Woods chip
- Woods chips: $50,000/416 = 120.2$ wafers needed
Markon chips: $25,000/240 = 104.2$ wafers needed

Therefore, the most lucrative split is 120 Woods wafers, 30 Markon wafers.

2. [20 = 10 x 2] You are designing a system for a real-time application in which specific deadlines must be met. Finishing the computation faster gains nothing. You find that your system can execute the necessary code, in the worst case, twice as fast

as necessary.

- a. How much energy do you save if you execute at the current speed and turn off the system when the computation is complete?
- b. How much energy do you save if you set the voltage and frequency to be half as much?

Solution

- a. 50%
- b. Energy = $\frac{1}{2}$ load $\times V^2$. Changing the frequency does not affect energy—only power. So the new energy is $\frac{1}{2}$ load $\times (\frac{1}{2} V)^2$, reducing it to about $\frac{1}{4}$ the old energy.

3. [20 = 4 x 5] When parallelizing an application, the ideal speedup is speeding up by the number of processors. This is limited by two things: percentage of the application that can be parallelized and the cost of communication. Amdahl's law takes into account the former but not the later.

- a. What is the speedup with N processors if 80% of the application is parallelizable, ignoring the cost of communication?
- b. What is the speedup with 8 processors if, for every processor added, the communication overhead is 0.5% of the original execution time?
- c. What is the speedup with 8 processors if, for every time the number of processors is doubled, the communication overhead is increased by 0.5% of the original execution time?
- d. What is the speedup with N processors if, for every time the number of processors is doubled, the communication overhead is increased by 0.5% of the original execution time?
- e. Write the general equation that solves this question: What is the number of processors with the highest speedup in an application in which $P\%$ of the original execution time is parallelizable, and, for every time the number of processors is doubled, the communication is increased by 0.5% of the original execution time?

Solution

- a. $1/((.2 + .8/N))$
- b. $1/((.2 + 8 \times 0.005 + 0.8/8)) = 2.94$
- c. $1/((.2 + 3 \times 0.005 + 0.8/8)) = 3.17$
- d. $1/((.2 + \log N \times 0.005 + 0.8/N))$
- e. $d/dN(1/((1 - P) + \log N \times 0.005 + P/N)) = 0$

4. [20 = 5 x 4] For the following assume that values A, B, and C reside in memory.

Also assume that instruction operation codes are represented in 8 bits, memory addresses are 64 bits, and register addresses are 6 bits.

For each instruction set architecture shown in Figure A.2 (*stack*, *accumulator*, *register-memory*, *register-register*), how many addresses, or names, appear in each instruction for the code to compute $C = A + B$, and what is the total code size?

Solution

1) Stack:

Push A // one address appears in the instruction, code size = 8 bits (opcode) + 64 bits (memory address) = 72 bits;

Push B // one address appears in the instruction, code size = 72 bits;

Add // zero address appears in the instruction, code size = 8 bits;

Pop C // one address appears in the instruction, code size = 72 bits;

Total code size = 72 + 72 + 8 + 72 = 224 bits.

2) Accumulator

Load A // one address appears in the instruction, code size = 8 bits (opcode) + 64 bits (memory address) = 72 bits;

Add B // one address appears in the instruction, code size = 72 bits;

Store C // one address appears in the instruction, code size = 72 bits;

Total code size = 72 + 72 + 8 + 72 = 216 bits.

3) Register-memory

Load R1, A // two addresses appear in the instruction, code size = 8 bits (opcode) + 6 bits (register address) + 64 bits (memory address) = 78 bits;

Add R3, R1, B // three addresses appear in the instruction, code size = 8 bits (opcode) + 6 bits (register address) + 6 bits (register address) + 64 bits (memory address) = 84 bits;

Store R3, C // two addresses appear in the instruction, code size = 78 bits;

Total code size = 78 + 84 + 78 = 240 bits.

4) Register-register

Load R1, A // two addresses appear in the instruction, code size = 8 bits (opcode) + 6 bits (register address) + 64 bits (memory address) = 78 bits;

Load R2, B // two addresses appear in the instruction, code size = 78 bits;

Add R3, R1, R2 // three addresses appear in the instruction, code size = 8 bits (opcode) + 6 bits (register address) + 6 bits (register address) + 6 bits (register address) = 26 bits;

Store R3, C // two addresses appear in the instruction, code size = 78 bits;

Total code size = 78 + 78 + 26 + 78 = 260 bits.