CENG3420 Homework 1

Due: Feb. 15, 2023

Solutions

All solutions should be submitted to the blackboard in the format of **PDF/MS Word**.

Q1 (10%) This is a question about integrated circuit cost. Assume that a wafer contains 4096 dies and a die has 0.125 defects on average, please answer the following sub-questions.

1. Calculate the yield of this wafer. (5%)
2. Assume that you wanted to spend 8 millions HKD on manufacturing, how much money can you save for manufacturing the same number of dies if the average defects of a die can be reduced to 0.1? (5%)

A1 These are suggested solutions.

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

   We have known that a die has 0.125 defects on average. Thus, Defects per area $\times$ Die area $= 0.125$ and Yield $= \frac{1}{(1+\frac{0.125}{2})^2} = 0.8858$.

2. Before optimization,

   $$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{Yield}} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times 0.8858}. \tag{2}$$

   After optimization,

   $$\text{Yield} = \frac{1}{(1 + \frac{\text{Defects per area} \times \text{Die area}}{2})^2} = \frac{1}{(1 + \frac{0.1}{2})^2} = 0.9070. \tag{3}$$

   $$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{Yield}} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times 0.9070}. \tag{4}$$

   The saved money is $8M * (\frac{0.9070}{0.8858} - 1) = 0.19M$. You can save 190k HKD.

Q2 (5%) Sort the computational performance of the following computers (from low to high):

1. Embedded computer
2. Personal computer
3. Mobile phone
4. Quad-CPU Server
5. Warehouse scale computer

A2 $(1) < (3) < (2) < (4) < (5)$

Q3 (5%) Suppose we developed a new processor that has 75% of the capacitive load of the older processor. Further, it can reduce voltage 15% compared to previous generation, which results in a 15% shrink in frequency. What is the impact on dynamic power? Give the ratio of $\frac{\text{Power}_{\text{new}}}{\text{Power}_{\text{old}}}$.

A3 0.4606

$$\text{Power} = \frac{1}{2} \times \alpha \times \text{Capacitive load} \times \text{Voltage}^2 \times \text{Frequency switched} \tag{5}$$

The power ratio between the new one and the old one is $0.75 \times 0.85^2 \times 0.85 = 0.4606$.

Q4 (20%) We have an `int` (32 bits) array named `arr0`. The pointer of `arr0`'s first element stored in register `a1`. Please answer the following questions.

1. How to put the fourth element of `arr0` to register `t1`? (5%)
2. How to calculate `t1` + 16? Please store the result in register `t2` (5%)
3. Find an efficient way to calculate `t2` /16 and `t2` %16. Please store the results in `t3` and `t4`, respectively. Note that / is an integer division and % is the modulo operation. (hint: using shift and logical operations) (10%)

A4
1. lw t1, 12(a1)
2. addi t2, t1, 16
3. `t2` /16: srli t3, t2, 4; `t2` %16: andi t4, t2, 0x0F.

Q5 (20%) We have an `int` (32 bits) array named `arr1`. The pointer of `arr1`'s first element stored in register `a2`. We also have the registers `t1 = 0xAAAAAAAA, t2 = 0xFEDCBA98`
Please answer the following questions:

1. For the register values shown above, what is the value of `t3` for the following sequence of instructions? (5%)

```
slli t3, t1, 4
srli t3, t3, 4
```

2. What is the value of `t3` for the following sequence of instructions? (5%)

```
slli t3, t2, 3
srai t3, t3, 3
```

3. Write a piece of assembly program to: (10%)
   - Store the result of `t1` & `t2` to register `t4`; (3%)
   - Store `t4` to the first element of `arr1`; (3%)
   - Store the lowest 8 bits of `t4` to the second element of `arr1`. (4%)

A5
1. 0x0AAAAAAA
2. 0xFEDCBA98

3. Results:
   - and t4, t1, t2
   - sw t4, 0(a2)
   - sb t4, 4(a2)

Q6 (20%) Consider the following RISC-V instructions:

```
li t1, 0
li t2, 1
li t3, 1
li t4, 10
LOOP:
beq t1, t4, DONE
add t5, t2, t3
addi t2, t3, 0
addi t3, t5, 0
addi t1, t1, 1
jal x0, LOOP
DONE:
# end of the program
```

1. How many times is the loop executed (between LOOP and DONE)? (5%)
2. List the value of `t2` at each loop iteration. (5%)
3. List the value of `t3` at each loop iteration. (5%)
4. What does this program do? (5%)

A6 1. 10

2. $\{1, 2, 3, 5, 8, 13, 21, 34, 55, 89\}$
3. $\{2, 3, 5, 8, 13, 21, 34, 55, 89, 144\}$
4. Calculating the Fibonacci sequence.

Q7 (20%) Write RISC-V instructions to implement the following functionalities.

1. $t2 = t1 * 4 + 7$ (5%)
2. $t3 = (t1 + t2)\%16$ (5%)
3. $t2 = t1!$ (hint: assume multiply instruction `mul` is available) (10%)

A7 1.

```
slli t2, t1, 2
addi t2, t2, 7
```

2.

```
add t3, t1, t2
andi t3, t3, 0x0F
```

3.

```
li t3, 0
li t2, 1
LOOP:
beq t1, t3, DONE
mul t2, t2, t1
addi t1, t1, -1
jal x0, LOOP
DONE:
```