

COE 308 – Computer Architecture

Assignment 1 Solution: Computer Abstractions and Technology

1. (5 pts) Find the word or phrase from the list below that best matches the description in the following questions. Each answer should be used only once.

Control

Wafer

Embedded system

Digital Video Disk (DVD)

Instruction set architecture

Server

Datapath

Transistor

Assembler

Cache

DRAM

Abstraction

Yield

Defect

- a) Approach to the design of hardware or software. The system consists of layers, with each lower layer hiding details from the level above.
- b) Computer inside another device used for running one predetermined application or collection of software.
- c) Interface that the hardware provides to the low-level software.
- d) Integrated circuit commonly used to construct main memory.
- e) Microscopic flaw in a wafer.
- f) Percentage of good dies from the total number of dies on the wafer.
- g) Small, fast memory that acts as a buffer for the main memory.
- h) Thin disk sliced from a silicon crystal ingot, which will be later divided into dies.
- i) Component of the processor that performs arithmetic operations.
- j) Component of the processor that tells the datapath what to do according to the instructions of the program.
- k) On/Off switch controlled by electricity.
- l) Computer used for running large programs for multiple users often simultaneously and typically accessed only by a network.
- m) Optical storage medium with a storage capacity of more than 4.7 GB.
- n) Program that converts symbolic versions of instructions into their binary formats.

Solution:

a) **Abstraction**

c) **Instruction set architecture**

e) **Defect**

g) **Cache**

i) **Datapath**

k) **Transistor**

m) **Digital Video Disk (DVD)**

b) **Embedded system**

d) **DRAM**

f) **Yield**

h) **Wafer**

j) **Control**

l) **Server**

n) **Assembler**

2. (2 pts) In a magnetic disk, the disks containing the data are constantly rotating. On average, it should take half a revolution for the desired data on the disk to spin under the read/write head. Assuming that the disk is rotating at 5400 RPM, what is the average time for the data to rotate under the disk head? What is the average time if the disk is spinning at 7200 RPM?

Solution:

Time for half revolution (5400 rpm) = $1 / 2 \times 1 \text{ min} / 5400 \text{ revolutions}$

Time for half revolution (5400 rpm) = $60 \text{ sec} / (2 \times 5400) = 0.00556 \text{ sec} = 5.56 \text{ ms}$

Time for half revolution (7200 rpm) = $1 / 2 \times 1 \text{ min} / 7200 \text{ revolutions}$

Time for half revolution (7200 rpm) = $60 \text{ sec} / (2 \times 7200) = 0.00417 \text{ sec} = 4.17 \text{ ms}$

3. (4 pts) The cost of an integrated circuit can be expressed in three simple equations:

$$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{yield}}$$

$$\text{Dies per wafer} = \frac{\text{Wafer area}}{\text{Die area}}$$

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

The following figure shows key statistics for DRAM production over 12 years:

Year	Capacity	Die area	Wafer diameter	Yield
1980	64K bits	0.16 cm ²	5 inches	48%
1983	256K bits	0.24 cm ²	5 inches	46%
1985	1024K bits	0.42 cm ²	6 inches	45%
1989	4096K bits	0.65 cm ²	6 inches	43%
1992	16384K bits	0.97 cm ²	8 inches	48%

- a) (1 pt) Given the increase in die area of DRAMs, what parameter must improve to maintain yield?
- b) (2 pts) Derive a formula for the improving parameter found in (a) from the other parameters.
- c) (1 pt) Using the formula in the answer to (b), what is the calculated improvement in that parameter between 1980 and 1992?

Solution:

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

If die area is increased then to keep the yield constant, we must improve (reduce) the defects per area.

b) **$Yield = 1 / (1 + Defects \text{ per area} \times Die \text{ area} / 2)^2$**

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

$(1 + Defects \text{ per area} \times Die \text{ area} / 2) = \frac{1}{\sqrt{Yield}}$

$$\text{Defects per area} = \left(\frac{2}{\text{Die area}} \right) \times \left(\frac{1}{\sqrt{\text{Yield}}} - 1 \right)$$

c) In 1980, $\text{Yield} = 48\%$, $\text{Die Area} = 0.16 \text{ cm}^2$.

$$\text{Defects per area} = \left(\frac{2}{0.16} \right) \times \left(\frac{1}{\sqrt{0.48}} - 1 \right) = 5.54 \text{ defects per cm}^2$$

In 1992, $\text{Yield} = 48\%$, $\text{Die Area} = 0.97 \text{ cm}^2$.

$$\text{Defects per area} = \left(\frac{2}{0.97} \right) \times \left(\frac{1}{\sqrt{0.48}} - 1 \right) = 0.91 \text{ defects per cm}^2$$

4. (3 pts) Assume you are in a company that will market a certain IC chip. The fixed costs, including R&D, fabrication and equipments, and so on, add up to \$500,000. The cost per wafer is \$6000, and each wafer can be diced into 1500 dies. The die yield is 50%. Finally, the dies are packaged and tested, with a cost of \$10 per chip. The test yield is 90%; only those that pass the test will be sold to customers. If the retail price is 40% more than the cost, at least how many chips have to be sold to break even?

Solution:

Number of good dies per wafer = $1500 \times 0.5 = 750$

Number of chips that are sold to customers per wafer = $750 \times 0.9 = 675$

Cost per wafer = $\$6000 + \$10 \times 750 = \$13500$

Retail price per wafer = $\$13500 \times 1.4 = \18900 (40% more than the cost)

Retail price per chip = $\$18900 / 675 = \28

Let W be the total number of wafers that must be sold:

Total cost = $\$500,000 + \$13,500 \times W$

Total retail price = $\$18,900 \times W$

To break even: $\$500,000 + \$13,500 \times W = \$18,900 \times W$

$W = 92.59$ wafers

Number of chips that must be sold = $92.59 \times 675 = 62,500$ chips

Review Exercises:

5. (4 pts) What are the unsigned and signed decimal values of the following binary and hexadecimal numbers?

a) 10110110

$$\text{Unsigned Value} = 128 + 32 + 16 + 4 + 2 = 182$$

$$\text{Signed Value} = -128 + 32 + 16 + 4 + 2 = -74$$

b) 11001100

$$\text{Unsigned Value} = 128 + 64 + 8 + 4 = 204$$

$$\text{Signed Value} = -128 + 64 + 8 + 4 = -52$$

c) 8A1F

$$\text{Unsigned Value} = 8 \cdot 16^3 + 10 \cdot 16^2 + 16 + 15 = 35359$$

$$\text{Signed Value} = 35359 - 2^{16} = -30177$$

d) C1B3

$$\text{Unsigned Value} = 12 \cdot 16^3 + 16^2 + 11 \cdot 16 + 3 = 49587$$

$$\text{Signed Value} = 49587 - 2^{16} = -15949$$

6. (2 pts) Carry the following additions. Indicate whether there is a carry or overflow?

a)
$$\begin{array}{r} \textcolor{red}{1111} \\ 11010010 \text{ (binary)} \\ + 10111101 \text{ (binary)} \\ \hline 10001111 \\ \text{Carry} = 1 \\ \text{Overflow} = 0 \\ \text{No overflow because operands} \\ \text{and result are negative} \end{array}$$

b)
$$\begin{array}{r} \textcolor{red}{1} \text{ } \textcolor{red}{11} \\ A1CF \text{ (hexadecimal)} \\ + B2D3 \text{ (hexadecimal)} \\ \hline 54A2 \\ \text{Carry} = 1 \\ \text{Overflow} = 1 \\ \text{Yes, there is an overflow because} \\ \text{operands are negative, but result is} > 0 \end{array}$$