EE 330

Homework 2 Solutions

Fall 2020

Solution 1

a) $Y_H = e^{-Ad} = e^{-1.75cm^2*2cm^{-2}} = 0.03$

b) We want $C_{good} = \frac{C_{Fab}}{Y}$ where $Y = Y_H * Y_S = 0.03 * 1 = 0.03$

and $C_{Fab} = \frac{C_{Wafer}}{A_{Wafer}} * A_{die} = \frac{1750\$}{\pi\left(\frac{12}{2}inc\right)^2} * 1.75cm^2 = \frac{1750\$}{\pi(15.24cm)^2} * 1.75cm^2 = \$4.197$

So $C_{good} = \frac{\$4.197}{0.03} = \$139.9$

c) YH is the probability that the die does not have a hard fault so 3% will not have a hard fault meaning this is a bad process.

Solution 2

a) $Y_H = e^{-Ad} \rightarrow e^{-A*1.5cm^{-2}} = 0.05 \rightarrow A = 2cm^2$

b) $C_{fab} = 5 * .05 = 0.25$

We want $A_{Wafer} = \frac{C_{Wafer}}{C_{Fab}} * A_{die} = \frac{810.73\$}{0.25\$} * 2cm^2 = 6485.84cm^2$

$A_{Wafer} = \pi R^2 \rightarrow R = 45.44cm = 17.89 inches$ So the Diameter is 35.78 inches

Solution 3

a) To begin, convert the die area (A_{die}) and the defect density (d) to the same units:

$A_{die} = 0.75mm^2$

$d = 1cm^{-2} = 0.01mm^{-2}$

To calculate the hard yield of the die, thus satisfying the first part of this question, recall that the Hard Fault model learned in class is $Y_H = e^{-Ad}$, where Y_H is the hard yield, A is the die area, and d is the defect density:

$Y_H = e^{-Ad} = e^{-0.75mm^2*0.01mm^{-2}} = 0.993$

b) We can calculate the die's overall yield (the second part of the question) by multiplying the Hard Yield and the Soft Yield together. In the problem statement, the soft yield is given as 0.99. Thus:

$Y = Y_H * Y_S = 0.993 * 0.99 = 0.983$

c) To satisfy the third part of this problem, we note that 0.983 is greater than 0.95, so the company would be willing to fabricate this die. We can determine the maximum size the die could be while maintaining this constraint by working backwards:

$$Y_{H,Limit} = \frac{Y}{Y_S} = \frac{0.95}{0.99} = 0.96$$

$$A = -\frac{\ln(Y_{H,Limit})}{d} = -\frac{\ln(0.96)}{0.01mm^{-2}} = 4.08mm^2$$

Solution 4

Recall that the Hard Fault model learned in class is as follows: $Y_H = e^{-Ad}$, where Y_H is the hard yield, A is the die area, and d is the wafer's defect density. Using this, we can calculate the expected yield rate of each vendor:

Vendor	**1**	**2**	**3**	**4**
Yield	0.427	0.361	0.331	0.331

We can then calculate the expected number of die that will fit on the wafers from each vendor by dividing the wafer area by the anticipated die area:

Vendor	**1**	**2**	**3**	**4**
Die per Wafer	1870	832	832	577

Finally, using the cost per wafer and the number of die per wafer, we can calculate the cost per die by dividing the cost per wafer by the number of die received from each wafer, and then dividing again by the expected yield:

$$C_{GoodDie} = \frac{Wafer\ Cost}{Die\ per\ Wafer * Yield}$$

This yields the following values for each vendor:

Vendor	**1**	**2**	**3**	**4**
Cost per Good Die	\$4.88	\$4.99	\$5.27	\$5.24

Clearly, the vendor who provides the lowest cost per good die is Vendor #1.

Solution 5

$Y_H = e^{-1*0.1}$

$Y_H = 0.905$

$Y = Y_S Y_H = 0.8 * 0.905$

$Y = 0.724\%$

Solution 6

It may initially be tempting to observe that, because the minimum feature size of the process has decreased from $65nm$ to $7nm$, that the die area decreases by a factor of $7/65$. This, however, is not the case. To begin, we must first determine the number of transistors in the original circuit:

$$A_{Transistor} = 65nm * 65nm = 4.225 * 10^{-11}cm^2$$

$$N_{Transistors} = \frac{A_{die}}{A_{Transistor}} = \frac{0.5cm^2}{4.225 * 10^{-11}cm^2} = 1.183 * 10^{10}$$

Then, we must determine how much area this collection of transistors takes in the new process:

$$A_{die} = N_{Transistors} * (7nm)^2 = 0.58mm^2$$

Thus, the new die size is expected to be about $0.58mm^2$. This results in 274,000 die being able to fit on a single $450mm$ wafer:

$$N_{Die} = \frac{A_{Wafer}}{A_{Die}} = \frac{\pi(225mm)^2}{0.58mm^2} = 274000$$

Solution 7

We need to normalize the Gaussian curve with standard deviation of 1.25mA and a mean of 0A by shifting our variable by the mean and dividing by the s.d.

$$z = \frac{x - mean}{s.d.} = \frac{3mA - 0}{1.25mA} = 2.4$$

Our normalized value is now 2.4 and since the device ideally has 0 current bias, we are looking at values between -3mA and 3mA, or normalized to -2.4 and 2.4 to get the probability. Since there is symmetry in the normalized curve, if we find $P(Z < -2.4)$ which equals $P(Z > 2.4)$ and subtract those from 1, we will get the probability that the current bias is under 3mA.

From the z-table $P(Z < -2.4) = 0.0082$ so there is a 0.0164 chance of the current bias being beyond 3mA so $P = 1 - 0.0164 = 0.9836 = 98.36\%$

If the mean is 0.1mA the z value changes so

$$z = \frac{x - mean}{s.d.} = \frac{3mA - 0.1mA}{1.25mA} = 2.32mA$$

And

$$z = \frac{x - mean}{s.d.} = \frac{-3mA - 0.1mA}{1.25mA} = -2.48mA$$

Another way to calculate is taking $P(Z < 2.32)$ and subtracting $P(Z < -2.48)$ so

$$P = 0.98983 - 0.00657 = 0.9833 = 98.33\%$$

Solution 8

The probability can be solved in two different ways. One way is to use the equation

P= 2*F_n(x)-1 = p = 2*F_n(1.25)-1 = 2 * 0.8944 - 1 = 0.7888

Another is to find P(Z < -1.25) and subtract it from P(Z < 1.25)

P = 0.8944 - 0.1056 = 0.7888

Solution 9

Six-sigma is a standard in which companies attempt to produce product at a yield of 6 sigma, or 99.99999980%. This is near impossible in the production of semiconductors because even the most cutting-edge manufacturing technology would have many more defects than allowed.

Solution 10

The most used device before the BJT and MOS was the vacuum tube, which was invented in 1910. Vacuum tubes phased out in favor of BJT and MOS devices because they were expensive, hot, heavy, large, and very fragile.

Solution 11

First, we start by getting the Z score for 90%

$P(X < Z < X)= 0.9$ or $P(Z<X)= 0.95$

$X = 1.645$

Next, we use the Z score to determine the standard deviation

$1.645 = (10-0)/ \sigma$

$\sigma = 6.08\ \mu V$

For the second part we know the Z = 6 so,

$6 = (10-0)/ \sigma$

$\sigma = 1.67\ \mu V$

Solution 11

$(45/2)^2\pi = 1590.4\ cm^2$

$(1590.4)/2 = 795.2$ die

$3000/(795*Y) = 5$

$Y=0.755$