EE 330 Homework 5 Solutions

These solutions use the 0.5μ and a λ of 0.3

1. Length of interconnect = $400 \lambda = 120 \, \mu m$

Width of interconnect = $2 \lambda = 0.6 \, \mu m$

No. of squares = $400/2 = 200$

Sheet resistance of interconnect = $23.5 \, ^\Omega/_{sq}$

Resistance = $23.5 * 200 = \mathbf{4.7 \, k\Omega}$

   Capacitance from interconnect to substrate

Capacitance of Poly 1 substrate from the table given = $84 \, ^{aF}/_{\mu m^2}$

Interconnect area = $0.6 \, \mu m * 120 \, \mu m = 72 \, \mu m^2$

Capacitance of the substrate = $84 \, ^{aF}/_{\mu m^2} * 72 \, \mu m^2 = \mathbf{6.048 \, fF}$

   Capacitance between metal and interconnect

Capacitance of Poly and Metal1 from the table given = $56 \, ^{aF}/_{\mu m^2}$

Area of contact between poly and metal = $72 \, \mu m^2$

Capacitance = $59 \, ^{aF}/_{\mu m^2} * 72 \, \mu m^2 = \mathbf{4.248 \, fF}$

2. Length of the interconnect = $200 \, \mu m$

Width of interconnect = $2 \, \mu m$

No. of squares = $200/2 = 100$

Resistance = $20 \, \Omega$

Sheet resistance = $20/100 = \mathbf{0.2 \, ^\Omega/_{sq}}$

Resistivity of copper = $17.2 \, n\Omega * m$

Thickness = Resistivity/Resistance = $\mathbf{86 \, nm}$

   For Ag =>

Resistivity of silver= $15.9 \, n\Omega * m$

Sheet resistance = Resistivity /thickness = $15.9 \, n\Omega * m \, / \, 86 \, nm = 0.185 \, ^\Omega/_{sq}$

Length = W*R/Rs = $\mathbf{216.4 \, um}$

3.

Overlap Cap			
Layers	Overlap Area (μm^2)	$aF/_{\mu m^2}$	Cap (aF)
Poly-Sub	89.1	84	7484.4
M1- Sub	4.86	27	131.22
M2-sub	15.12	12	181.44
M3-Sub	5.4	7	37.8
M1-Poly	24.3	56	1360.8
M2-Poly	25.92	15	388.8
M3-Poly	12.42	9	111.78
M2-M1	9.72	31	301.32
M3-M1	4.86	13	63.18
M3-M2	6.48	35	226.8
Fringe Cap			
Layers	Length (µm)	aF/(µm)	Cap (af)
Poly-Sub	37.8	0	0
M1- Sub	9	49	441
M2-sub	15.6	33	514.8
M3-Sub	9.6	23	220.8
M1-Poly	5.4	59	318.6
M2-Poly	7.2	38	273.6
M3-Poly	3.6	28	100.8
M2-M1	5.4	51	275.4
M3-M1	3.6	34	122.4
M3-M2	7.2	52	374.4

4. Sheet resistance for high resistance poly = $44\Omega\backslash\square$

Resistance = 3000 Ω

No. of squares = 3000/44 = 68

L = 3W; Let's use a 2λ x 2λ for one square. The following layout is approximately 68 squares and the bounding rectangle meets the aspect ratio requirements.
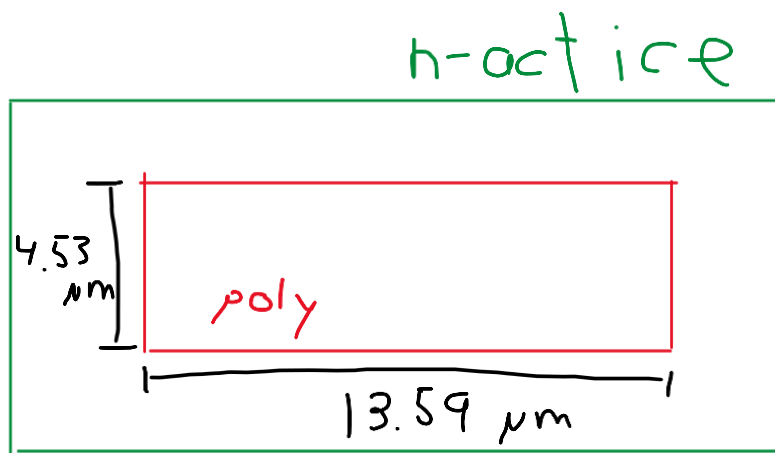
A

28λ

B

20λ
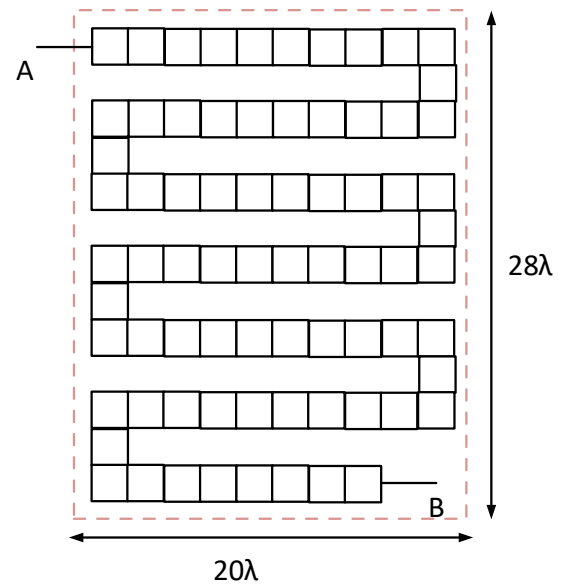
Problem 5.

Using N^+ $active$ and $Poly$ 1. Since this has the highest capacitance.

Capacitance of : $C_{N+\_Poly} = 2434\ ^{aF}/_{\mu m^2}$

Area of Capacitance: $(C = C_d * A) : A = {^C}/_{C_d} = \dfrac{150\ fF}{2434\ ^{aF}/_{\mu m^2}} = 61.63\ \mu m^2$

h-actice

4.53 μm

poly

13.59 μm

Problem 6

Nominal Value of resistance $= \rho \cdot \dfrac{Length}{Area}$

From table/calculator relating ρ to resistivity

→ $\rho = 22.34 \ \Omega \cdot cm = 22.34 \times 10^{-2} \ \Omega m$

→ height (thickness) $= 0.1 \ \mu m$

→ Area $= 0.4 \ \mu m^2$

Length $= 50 \mu m$

⇒ Nominal Value of resistance $= \dfrac{50}{0.4 \times 10^{-6}} \times 22.34 \times 10^{-2}$

$= 27.925 \ M\Omega$

7. Part A:

Begin by calculating the number of squares in each serpentine structure. We can calculate the number of horizontal lines in the serpentine structures as follows:

$$N_{Horizontal} = \frac{Length_{die}}{Width_{Interconnect} + Width_{Spacing}} \quad \frac{1cm}{0.2\mu m} = = 50000$$

So we have 50,000 horizontal lines, each $1cm$ long. This amounts to 5×10^9 squares.

To connect these lines, we have $N_{Horizontal} - 1$ vertical segments, each 0.1μ wide. This amounts to 49,999 squares.

In total, we have $5 \times 10^9 + 49999$ squares per resistor. Each metal layer has a resistivity of $0.12\Omega/sq$, so each resistor has a resistance of $600M\Omega$. When combined in parallel, we have a resistance of $200M\Omega$.

Part B:

Each resistor is only $0.1\mu m$ thick, so each can carry a maximum density of $150\mu A$. Placed in parallel, this means the total resistor can carry up to $450\mu A$.

Part C:

$$P = I^2R = [450\mu A]^2[200M\Omega] = 40.5W$$

Problem 8   If the resistance in the interconnect is neglected, it acts as a capacitor in parallel with the input capacitance of the second inverter. $C_I = (C_\delta)(W L)$

a) $R_{p\delta} = 2K$ $t_{HL} = R_{p\delta}(C_L)$ $C_\delta = 27af/\mu^2$

$C_I = (.6\mu)^2(27af/\mu^2)$

$= 9.7Af$

$C_L = 3fF + 9.7aF \approx 3.01 fF$

$\therefore t_{HL} \approx 6.02 psec$

b), If $L = 200\mu$

$C_I = (.6)(200) 27af/\mu^2 = 3.24 fF$

$\therefore C_L = 3fF + 3.24fF = 6.24fF$

$\therefore t_{HL} = (2k)(6.24fF) = 12.5 psec$

c) The only change with poly (again negleting the interconnect resistance) is

Cd=84af/u² so Cᵢ=(0.6)(200)84af/u² = 10.1fF so C_L=13.1fF and thus

tHL=(2K)(10.1fF)=20.2psec