EE 330 Homework 5 Solutions Fall 2025

1. Length of interconnect = $120\ \mu m$

Width of interconnect = $0.6\ \mu m$

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

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

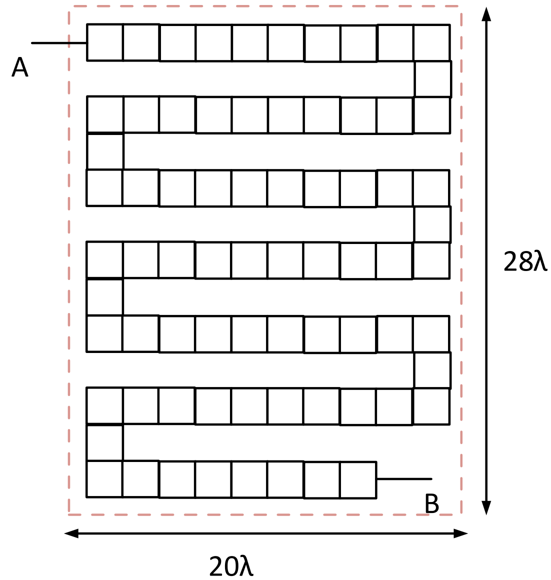
Fringe Cap			
Layers	Length (µm)	aF/(µm)	Cap (af)
Poly-Sub	37.8	0	0
M1- Sub	9	49	441
M2-sub	15.6	33	514.8
M3-Sub	9.6	23	220.8
M1-Poly	5.4	59	318.6
M2-Poly	7.2	38	273.6
M3-Poly	3.6	28	100.8
M2-M1	5.4	51	275.4
M3-M1	3.6	34	122.4
M3-M2	7.2	52	374.4

4. Sheet resistance for high resistance poly = 44Ω\□

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.

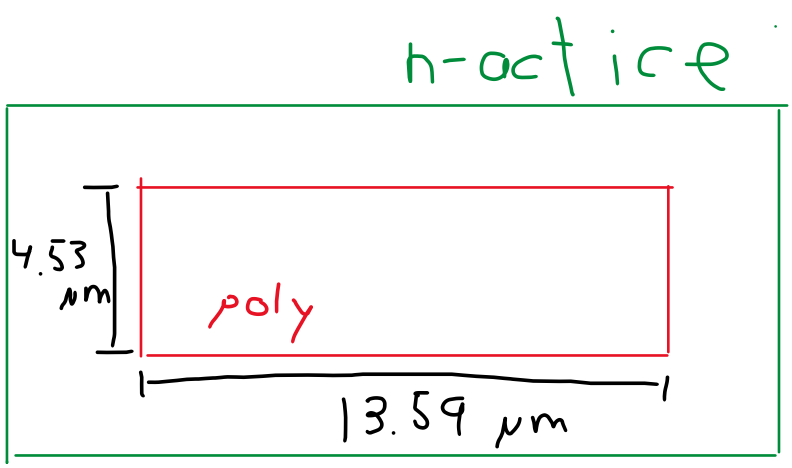


Problem 5.

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



Problem 6

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

From table/calculator relating ρ to resistivity

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

$\rightarrow$ height (thickness) $= 0.1 \mu m$

$\rightarrow$ Area $= 0.4\ \mu m^2$

Length $= 50 \mu m$

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

$= 27.925\ M\Omega$

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:

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

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 0.1μm thick, so each can carry a maximum density of 150μA. Placed in parallel, this means the total resistor can carry up to 450μA.

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.

$C_I = (C_d)(WL)$

$C_d = 27 af/\mu^2$

a) $R_{pd} = 2K$ $t_{HL} = R_{pd}(C_L)$

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

$= 9.7Af$

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

$\therefore t_{HL} \simeq 6.02$ 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/u^2 so C_I=(0.6)(200)84af/u^2 = 10.1fF so C_L=13.1fF and thus

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