EE 330 Homework 5 Solutions

1. Length of interconnect = 60um
Width of interconnect = 0.6um
No. of squares = 200/2 = 100.

Sheet resistance of interconnect = 23.5 Ω/square

Resistance = 23.5*100 = 2350Ω

Capacitance from interconnect to substrate

Capacitance of Poly 1 substrate from the table given = 84aF/um^2

Interconnect area = 0.6*60 = 36um^2

Capacitance of the substrate= 84 * 10^-18 *36 = 3.024fF

Capacitance between metal and interconnect

Capacitance of Poly and Metal1 from the table given = 56aF/um^2

Area of contact between poly and metal = 36um^2

Capacitance = 56 * 10^-18 *36 = 2.016fF

2. Length of the interconnect = 300um
Width of interconnect = 2um
No. of squares = 300/2 = 150.
Resistance = 20 Ω
Sheet resistance = 20/150 = 0.133 Ω/square
Resistivity of copper = 1.72 * 10^-8 Ωm
Thickness = Resistivity/Resistance = 129.3nm

For Ag =>

Sheet resistance = Resistivity /thickness = 1.59 * 10^-8/ 12.93* 10^-8 = 0.123

Length = W*R/Rs = 325um

3.

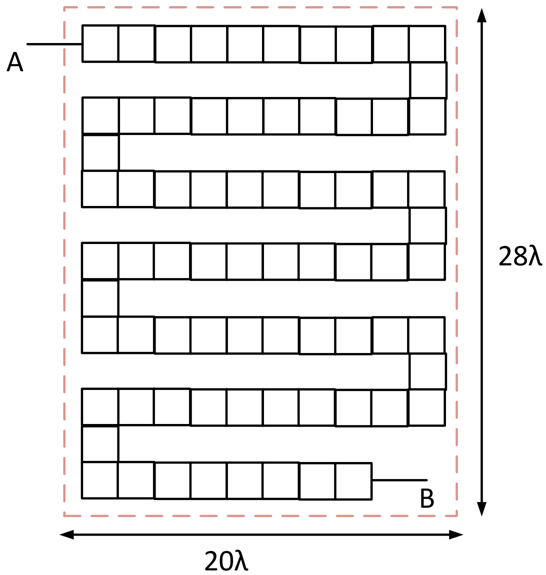
Overlap Cap			
Layers	Overlap Area (µm2)	aF/(µm2)	Cap (af)
Poly-Sub	89.1	84	7484.4
M1- Sub	4.86	27	131.22
M2-sub	15.12	12	181.44
M3-Sub	5.4	3	16.2
M1-Poly	24.3	56	1360.8
M2-Poly	25.92	15	388.8
M3-Poly	12.42	9	111.78
M2-M1	9.72	31	301.32
M3-M1	4.86	13	63.18
M3-M2	6.48	35	226.8
Fringe Cap			
Layers	Length (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.

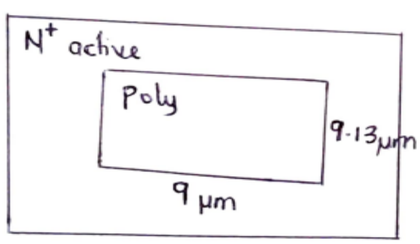


Problem 5.

Designing a capacitor using N^+ active and Poly 1

$\rightarrow$ $C = C_p \times \text{Area} \rightarrow 200 \times 10^{-15} = 2434 \times 10^{-18} \times A$

$\rightarrow$ $\text{Area} = \dfrac{200 \times 10^{-15}}{2434 \times 10^{-18}} = 82.17\ \mu m^2$



Problem 6

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

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 $= 50\mu m$

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

$$= 27.925\ M\Omega$$

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 $0.1\mu m$ 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:

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

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

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

$= 9.7Af$

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

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

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/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