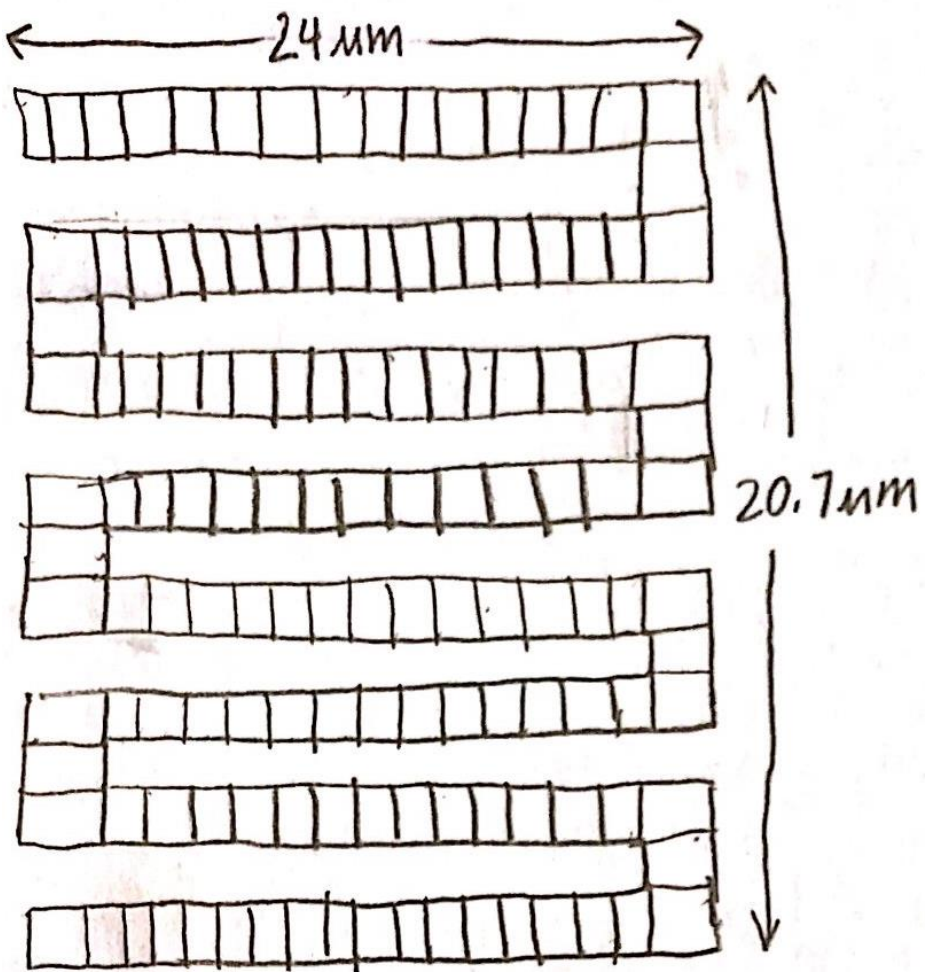
Homework 5 Spring 2018 TA: George Alphonse

Problem 1:

Sheet Resistance of poly is 23.5 Ω/■ => $\frac{3000}{23.5} = 127.7$

Min Poly width in resistor is 1.5 µm and min spacing is 0.9 µm.

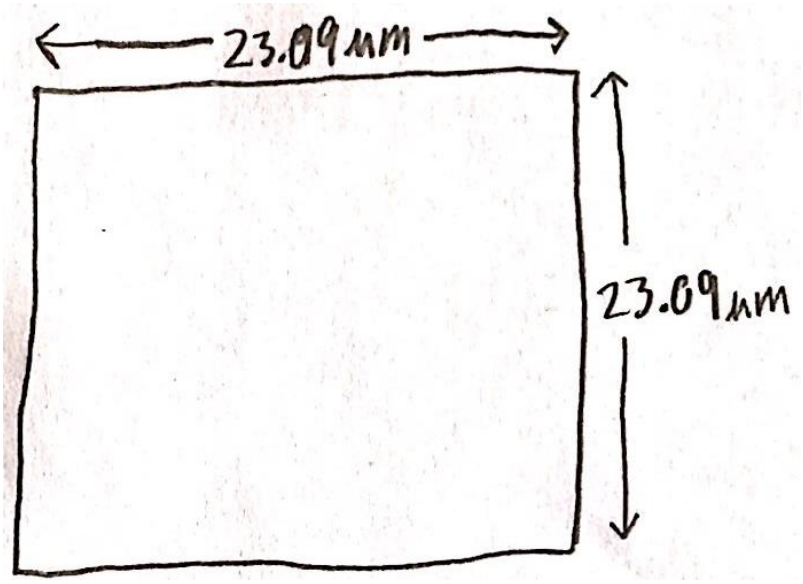
If we use 16■ X 8 lines we get 14 corners $=> 16 * 8 + 7 - 14 * .45 = 128.7■ = 3042.5\ \Omega$



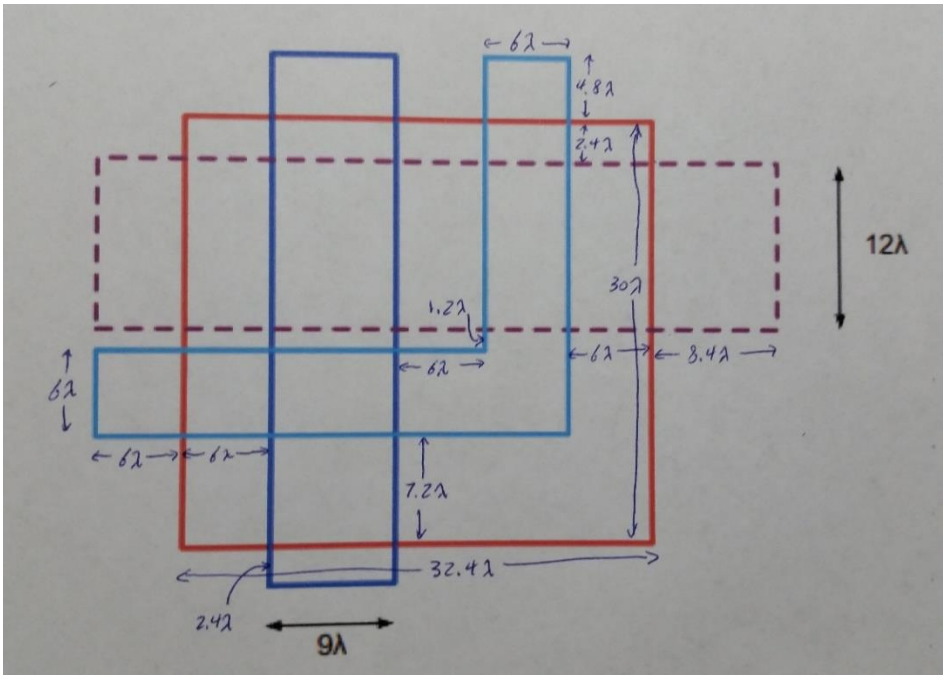
Problem 2:

Using poly and poly2 => 938 aF/µm^2

$$A_C = \frac{0.5 * 10^{-12}\, F}{938 * 10^{-18}\, F/\mu m^2} = 533\ \mu m^2 \Rightarrow \sqrt{A_C} = 23.09 \mu m$$



Problem 3:



$$C_{32} = A_{32} * 35\frac{aF}{\mu m^2} = \lambda^2 * (6 * 9) = 226.8\ aF$$

$$C_{31} = A_{31} * 13\frac{aF}{\mu m^2} = \lambda^2 * (12 * 6) = 63.18\ aF$$

$$C_{3P} = A_{3P} * 9\frac{aF}{\mu m^2} = \lambda^2 * (6 * 6 + 6 * 12 + 6 * 1.2) = 93.312\ aF$$

$$C_{3S} = A_{3S} * 7\frac{aF}{\mu m^2} = \lambda^2 * (6 * 6 + 6 * 4.8) = 40.82\ aF$$

$$C_{21} = A_{21} * 31\frac{aF}{\mu m^2} = \lambda^2 * (12 * 9) = 301.32\ aF$$

$$C_{2P} = A_{2P} * 15\frac{aF}{\mu m^2} = \lambda^2 * (6 * 12 + 12 * 18) = 388.8\ aF$$

$$C_{2S} = A_{2S} * 12\frac{aF}{\mu m^2} = \lambda^2 * (6 * 12 + 12 * 8.4) = 186.62\ aF$$

$$C_{1P} = A_{1P} * 56\frac{aF}{\mu m^2} = \lambda^2 * (30 * 9) = 1360.8\ aF$$

$$C_{1S} = A_{1S} * 27\frac{aF}{\mu m^2} = \lambda^2 * (2.4 * 9 + 4.8 * 9) = 157.46\ aF$$

$$C_{PS} = A_{PS} * 84\frac{aF}{\mu m^2} = \lambda^2 * (30 * 32.4) = 7348.32\ aF$$

Problem 4:

$$R(320) = 4534 * \left(1 + (320 - 250) * \left(\frac{1200}{10^6}\right)\right) = 4914\ \Omega$$

Problem 5:

Using the resistivity calculator at http://cleanroom.byu.edu/ResistivityCal, the resistivity equals

ρ = 22.34 Ω-cm = 223400 Ω-um

$$R = \rho * \left(\frac{L}{W * t}\right) = 223.4 * 10\text{^}3 * \left(\frac{50}{2 * t}\right) = \frac{5.59 * 10^6}{t}\ \Omega$$

Problem 6:

Value of combination is $R_T = R_1 + R_2$

Substitution and algebra yield $R_T = (R_1 + R_2) * (1 + \frac{\Delta T}{10^6} * \left(\frac{R_1}{R_1+R_2} * TCR_1 + \frac{R_2}{R_1+R_2} * TCR_2\right)$

This matches the form of the original equation if $TCR_T = \left(\frac{R_1}{R_1+R_2} * TCR_1 + \frac{R_2}{R_1+R_2} * TCR_2\right)$

=> $TCR_T = 133.33\ ppm/℃$

The TCR is $\frac{1400}{133.33} = 10.5$ times less than just an n+ doped resistor.

Problem 7:

$$R = R_s * \left(\frac{L}{W}\right) = 23.5 * \left(\frac{100}{1}\right) = 2350\ \Omega$$

$$C_{PS} = \left(84 \frac{aF}{\mu m^2}\right) * (100 * 1) = 8.4\ fF$$

$$C_{P2} = \left(56 \frac{aF}{\mu m^2}\right) * (100 * 1) = 5.6\ fF$$

Problem 8:

$$I_d = J_s A \left(e^{\frac{V_D}{V_T}} - 1\right) = \left(50um^2 * \frac{10^{-15}A}{um^2}\right) * \left(e^{\frac{0.5V}{26mV}} - 1\right) = 78.2\ uA$$

$$I_d = J_s A \left(e^{\frac{V_D}{V_T}} - 1\right) = \left(50um^2 * \frac{10^{-15}A}{um^2}\right) * \left(e^{\frac{0.6V}{26mV}} - 1\right) = 3.40\ mA$$

Problem 9:

$$I_d = \left(\frac{10^{-15}A}{um^2} * 200\ um^2\right)\left(e^{\frac{V_D}{26mV}} - 1\right)$$

$$V_x - V_R - V_D = 10V - I_d(2k\Omega) - V_D = 0$$

Solve system of equations: $I_D = 4.71\ mA$

Problem 10:

$$I_d = \left(\frac{10^{-15}A}{um^2} * 200\ um^2\right)\left(e^{\frac{V_D}{26mV}} - 1\right)$$

$$V_x - V_R - V_D = 520mV - I_d(2k\Omega) - V_D = 0$$

Solve system of equations: $I_D = 41.1\ uA$

Problem 11 and 12:

```
/home/yjchean/ee330/verilog/decoder3_to_8.v (/decoder3_to_8_TB/D328) - Default *
Ln#
1  `timescale 1ns/1ps
2  module decoder3_to_8(Y7, Y6, Y5, Y4, Y3, Y2, Y1, Y0, A, B, C, En);
3  //Define input and output pins
4   input A, B, C;
5   input En; //Enable line, usually 1
6   output Y7, Y6, Y5, Y4, Y3, Y2, Y1, Y0;
7
8   assign {Y7,Y6,Y5,Y4,Y3,Y2,Y1,Y0} =
9
10   ( {En,A,B,C} == 4'b1000) ? 8'b0000_0001 :
11   ( {En,A,B,C} == 4'b1001) ? 8'b0000_0010 :
12   ( {En,A,B,C} == 4'b1010) ? 8'b0000_0100 :
13   ( {En,A,B,C} == 4'b1011) ? 8'b0000_1000 :
14   ( {En,A,B,C} == 4'b1100) ? 8'b0001_0000 :
15   ( {En,A,B,C} == 4'b1101) ? 8'b0010_0000 :
16   ( {En,A,B,C} == 4'b1110) ? 8'b0100_0000 :
17   ( {En,A,B,C} == 4'b1111) ? 8'b1000_0000 :
18                              8'b0000_0000; //if all no input
19
20
21   endmodule
22
```

Figure A: 3-to-8 decoder Verilog

```
/home/yjchean/ee330/verilog/decoder3_to_8_TB.v (/decoder3_to_8_TB) - Default
Ln#
1   `timescale 1ns/1ps
2
3   module decoder3_to_8_TB();
4     reg A,B,C,En;
5     wire Y7, Y6, Y5, Y4, Y3, Y2, Y1, Y0;
6     decoder3_to_8 D328(Y7, Y6, Y5, Y4, Y3, Y2, Y1, Y0, A, B, C, En);
7
8     initial
9     begin
10      En=1'b1;
11      A=1'b0;  B=1'b0;  C=1'b0;  #20;
12      A=1'b0;  B=1'b0;  C=1'b1;  #20;
13      A=1'b0;  B=1'b1;  C=1'b0;  #20;
14      A=1'b0;  B=1'b1;  C=1'b1;  #20;
15      A=1'b1;  B=1'b0;  C=1'b0;  #20;
16      A=1'b1;  B=1'b0;  C=1'b1;  #20;
17      A=1'b1;  B=1'b1;  C=1'b0;  #20;
18      A=1'b1;  B=1'b1;  C=1'b1;  #20;
19      En=1'b0;
20
21    end
22  endmodule
```

Figure B: 3-to-8 decoder test bench Verilog

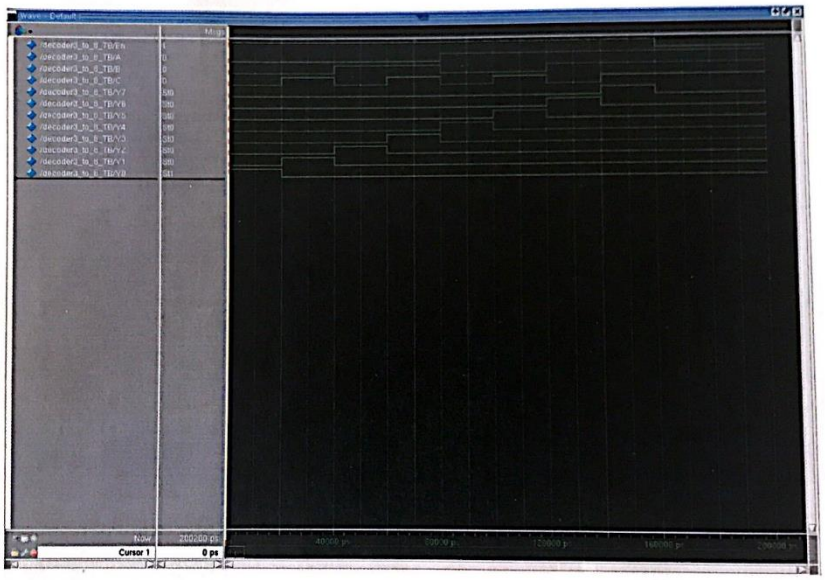


Figure C: Simulation waveforms of 3-to-8 decoder