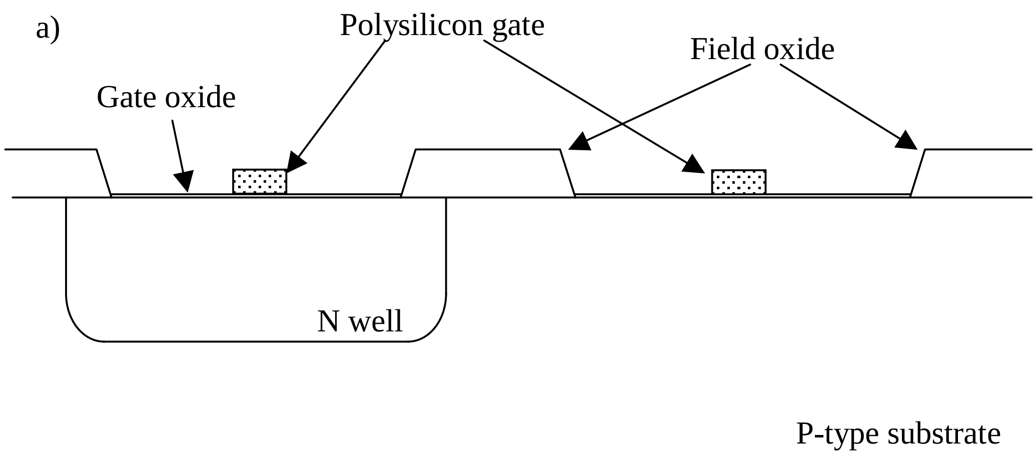
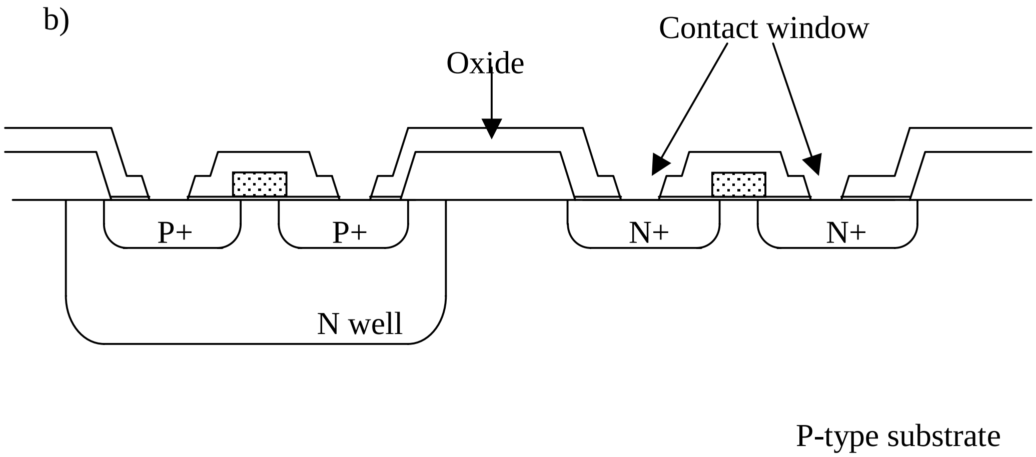
Homework #2 Solution

2.1 CMOS process flow

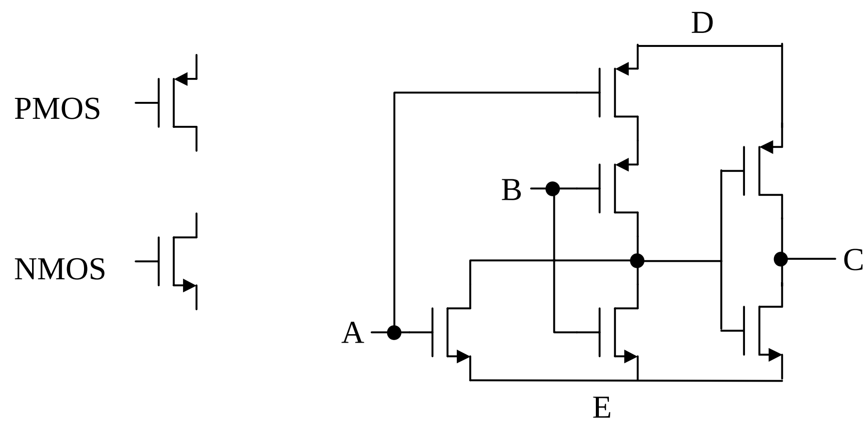
a)



b)

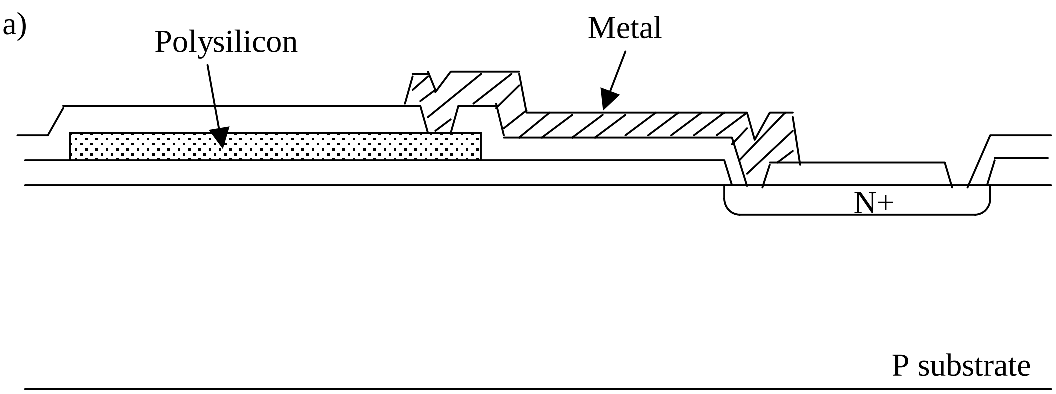


2.2 CMOS circuit



2.3 IC resistors

a)



b) Polysilicon: 14 squares, 2 contact regions & 1 corner
Metal: 2 squares, 2 contact regions
N+ doping: 3 squares, 2 contact regions

Number of squares:
$N_{polysilicon}$=14+2×0.65+0.56=15.86
N_{metal}=2+2×0.65=3.3
N_{N+}=3+2×0.65=4.3

R_{BC}=10Ω×15.86+0.01Ω×3.3+100Ω×4.3=588.633Ω

Since the resistance of metal is very small, you can neglect metal resistance in your calculation

2.4 IC resistors

a) The sheet resistance of N+ doping R_{N+} is 100Ω/square, which is defined as a function of electron mobility μ_n and doping concentration N_d:

$$R_{N+} = \frac{1}{q \cdot \mu_n \cdot N_d \cdot t}$$

where $q = 1.6 \cdot 10^{-19} C$, $t = 0.5 \cdot 10^{-4} cm$

$$N_d = \frac{1}{q \cdot \mu_n \cdot R_{N+} \cdot t} = \frac{1}{1.6 \cdot 10^{-19} C \cdot \mu_n \cdot 100\Omega \cdot 0.5 \cdot 10^{-4} cm}$$

Since electron mobility is a function of the doping concentration, several iterations are needed in your calculation to get within 20%.

The other way to solve this problem is to draw electron mobility as a function of the Doping concentration and compare it with the curve of electrons in Figure 2.8. The doping concentration at the cross point of the two curves will be the solution to this problem.

$$N_d \approx 1.5 \cdot 10^{19} cm^3$$

b) $R_1 = \overline{R_1} \pm \delta_{R1} = 10k\Omega \pm 500\Omega$
$R_2 = \overline{R_2} \pm \delta_{R2} = 5k\Omega \pm 400\Omega$

$$R_1 + R_2 = (\overline{R_1} \pm \delta_{R1}) + (\overline{R_2} \pm \delta_{R2}) = (\overline{R_1} + \overline{R_2}) \pm \delta_{R1} \pm \delta_{R2} = \overline{R_1 + R_2} \pm \delta_{R1+R2}$$

where $\overline{R_1} + \overline{R_2} = \overline{R_1 + R_2}$ and $\pm \delta_{R1} \pm \delta_{R2} = \pm \delta_{R1+R2}$

If δ_{R1} and δ_{R2} are independent and R_1, R_2 have the Gaussian, or normal, probability distribution.

$$\delta_{R1+R2} = \sqrt{\delta_{R1}^2 + \delta_{R2}^2} = \sqrt{(500\Omega)^2 + (400\Omega)^2} \approx 640\Omega$$

The uncertainty in R_1+R_2 is 640Ω.