

VJ.1.

$$T = 300K$$

$$U = 0V$$

$$N_A = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_D = 10^{16} \text{ cm}^{-3}$$

$$S = 25 \cdot 10^{-6} \cdot 10^4 = 25 \cdot 10^{-2} \text{ cm}^2$$

$$d_B, C_B = ?$$

$$\epsilon_0 = 8,854 \cdot 10^{-14} \text{ F/cm}$$

$$\epsilon_{Si} = 11,7$$

$$\epsilon = 1,04 \cdot 10^{-12} \text{ F/cm}$$

$$d_B = \sqrt{\frac{2 \epsilon_0 \epsilon_{Si}}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) (U_k - U)}$$

$$U_k = U_T \ln \left(\frac{n_{on} p_{op}}{n_i^2} \right)$$

$$C_B = \epsilon_0 \epsilon_{Si} \frac{S}{d_B}$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3} \ll N_A, N_D$$

$$n_{on} \approx N_D, p_{op} \approx N_A$$

$$U_k = \frac{300}{11600} \cdot \ln \left(\frac{N_D \cdot N_A}{n_i^2} \right) = 0,797V$$

$$d_B = 3,24 \cdot 10^{-5} \text{ cm}$$

$$C_B = 7,99 \cdot 10^{-9} \text{ F}$$

nF

VJ.2.

$$T = 300K$$

$$U = -3V$$

$$N_A = 5 \cdot 10^{16} \text{ cm}^{-3}$$

$$N_D = 10^{15} \text{ cm}^{-3}$$

$$S = 50 \cdot 10^{-2} \text{ cm}^2$$

$$d_B, C_B = ?$$

$$U_k = U_T \ln \left(\frac{N_D N_A}{n_i^2} \right)$$

$$U_k = 0,677V$$

$$d_B = \sqrt{\frac{2 \epsilon}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) (U_k - U)}$$

$$d_B = 2,2 \cdot 10^{-4} \text{ cm}$$

$$C_B = \epsilon \frac{S}{d_B} = 2,35 \cdot 10^{-9} \text{ F}$$

nF

VJ.3.

$$T = 300K$$

$$U = 0,3V$$

$$N_A = 5 \cdot 10^{16} \text{ cm}^{-3}$$

$$N_D = 10^{15} \text{ cm}^{-3}$$

$$S = 50 \cdot 10^{-2} \text{ cm}^2$$

$$U_K = 0,677V$$

$$d_B = 7,06 \cdot 10^{-5} \text{ cm}$$

$$C_B = \epsilon \frac{S}{d_B}$$

$$C_B = 7,34 \cdot 10^{-9} \text{ F}$$

nF

VJ.4.

$$T = 350K$$

$$U = 0V$$

$$N_A = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$S = 100 \cdot 10^{-2} = 1 \text{ cm}^2$$

$$d_B, C_B = ?$$

$$n_i(350) = 4,96 \cdot 10^{11} \text{ cm}^{-3}$$

$$n_i \ll N_A, N_D$$

$$n_{om} \approx N_D, \quad p_{op} \approx N_A$$

$$U_K = U_T \ln \left(\frac{N_D N_A}{n_i^2} \right)$$

$$U_K = 0,695V$$

$$d_B = 4,26 \cdot 10^{-5} \text{ cm}$$

$$C_B = \epsilon \frac{S}{d_B} = 2,43 \cdot 10^{-8} \text{ F}$$

VJ.5.

$$T = 350K$$

$$U = -2V$$

$$N_A = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$S = 1 \text{ cm}^2$$

$$d_B, C_B = ?$$

$$n_i = 4,96 \cdot 10^{11} \text{ cm}^{-3}$$

$$U_K = 0,695V$$

$$d_B = \sqrt{\frac{2\epsilon}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) (U_K - U)} = 8,396 \cdot 10^{-5} \text{ cm}$$

$$C_B = \epsilon \frac{S}{d_B} = 1,234 \cdot 10^{-8} \text{ F}$$

VJ. 6.

$$N_D = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_A = 10^{16} \text{ cm}^{-3}$$

$$\mu_n = 800 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 280 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,8 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 0,5 \cdot 10^{-6} \text{ s}$$

$$S = 10^{-2} \text{ cm}^2$$

$$T = 300 \text{ K}$$

$$W_m \gg L_p$$

$$W_p \gg L_n$$

$$U = 0,6 \text{ V}$$

$$m = 1$$

$$I_s, I_D = ?$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{L_n} + D_p \frac{p_{op}}{L_p} \right)$$

$$D_n = U_T \mu_n = 20,69 \text{ cm}^2/\text{V}$$

$$D_p = U_T \mu_p = 7,24 \text{ cm}^2/\text{V}$$

$$L_n = \sqrt{D_n \tau_n} = 4,068 \cdot 10^{-3} \text{ cm}$$

$$L_p = \sqrt{D_p \tau_p} = 1,9 \cdot 10^{-3} \text{ cm}$$

$$n_{op} = \frac{n_i^2}{N_A} = 2,1 \cdot 10^4 \text{ cm}^{-3}$$

$$p_{op} = \frac{n_i^2}{N_D} = 420,5 \text{ cm}^{-3}$$

$$I_s = 1,734 \cdot 10^{-13} \text{ A}$$

$$I_D = I_s \left(e^{\frac{U}{mU_T}} - 1 \right)$$

$$I_D = 2,06 \cdot 10^{-3} \text{ A}$$

mA

VJ. 7.

$$N_D = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_A = 10^{16} \text{ cm}^{-3}$$

$$\mu_n = 800 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 280 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,8 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 0,5 \cdot 10^{-6} \text{ s}$$

$$S = 10^{-2} \text{ cm}^2$$

$$T = 350 \text{ K}$$

$$W_m \gg L_p$$

$$W_p \gg L_n$$

$$U = 0,6 \text{ V}$$

$$m = 1$$

$$n_i = 4,96 \cdot 10^{11} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{L_n} + D_p \frac{p_{op}}{L_p} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 2,46 \cdot 10^7 \text{ cm}^{-3}$$

$$p_{op} = \frac{n_i^2}{N_D} = 4,92 \cdot 10^5 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 24,14 \text{ cm}^2/\text{V}$$

$$D_p = U_T \mu_p = 8,45 \text{ cm}^2/\text{V}$$

$$L_n = \sqrt{D_n \tau_n} = 4,395 \cdot 10^{-3} \text{ cm}$$

$$L_p = \sqrt{D_p \tau_p} = 2,055 \cdot 10^{-3} \text{ cm}$$

$$I_s = 2,19 \cdot 10^{-10} \text{ A}$$

$$I_D = I_s \left(e^{\frac{U}{mU_T}} - 1 \right) = 0,095 \text{ A} = 95 \text{ mA}$$

VJ. 8

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$N_A = 10^{17} \text{ cm}^{-3}$$

$$\mu_n = 700 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 320 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,5 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 0,8 \cdot 10^{-6} \text{ s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 300 \text{ K}$$

$$W_n = 1,5 \cdot 10^{-4} \text{ cm}$$

$$W_p = 2 \cdot 10^{-4} \text{ cm}$$

$$U = 0,5 \text{ V}$$

$$m = 1$$

$$I_S, I_D = ?$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3}$$

$$I_S = q S \left(D_n \frac{n_{op}}{W_p} + D_p \cdot \frac{p_{op}}{W_n} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 2,1 \cdot 10^3 \text{ cm}^{-3}$$

$$p_{op} = 4,21 \cdot 10^4 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 18,1 \text{ cm}^2/\text{s}$$

$$D_p = 8,276 \text{ cm}^2/\text{s}$$

$$I_S = 4,02 \cdot 10^{-13} \text{ A}$$

$$I_D = I_S \left(e^{\frac{U}{m U_T}} - 1 \right)$$

$$I_D = 1 \cdot 10^{-4} \text{ A} = 0,1 \text{ mA}$$

VJ. 9

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$N_A = 10^{17} \text{ cm}^{-3}$$

$$\mu_n = 600 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 300 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,5 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 0,8 \cdot 10^{-6} \text{ s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 350 \text{ K}$$

$$W_n = 1,5 \cdot 10^{-4} \text{ cm}$$

$$W_p = 2 \cdot 10^{-4} \text{ cm}$$

$$U = 0,5 \text{ V}$$

$$m = 1$$

$$I_S, I_D = ?$$

$$n_i = 4,96 \cdot 10^{11} \text{ cm}^{-3}$$

$$I_S = q S \left(D_n \frac{n_{op}}{W_p} + D_p \cdot \frac{p_{op}}{W_n} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 2,46 \cdot 10^6 \text{ cm}^{-3}$$

$$p_{op} = 4,92 \cdot 10^7 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 18,1 \text{ cm}^2/\text{s}$$

$$D_p = 9,05 \text{ cm}^2/\text{s}$$

$$I_S = 5,105 \cdot 10^{-10} \text{ A}$$

$$I_D = 8,03 \text{ mA}$$

VJ. 10.

$$N_D = 5 \cdot 10^{14} \text{ cm}^{-3}$$

$$N_A = 10^{14} \text{ cm}^{-3}$$

$$\mu_n = 200 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 280 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,8 \mu\text{s}$$

$$\tau_p = 0,4 \mu\text{s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 300 \text{ K}$$

$$W_n = 2 \cdot 10^{-4} \text{ cm}$$

$$L_n \ll W_p$$

$$U = 0,5$$

$$m = 1$$

$$I_s, I_D = ?$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{L_n} + D_p \frac{p_{op}}{W_n} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 2,1 \cdot 10^4 \text{ cm}^{-3}$$

$$p_{op} = 420,5 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 20,689 \text{ cm}^2/\text{s}$$

$$D_p = U_T \mu_p = 7,24 \text{ cm}^2/\text{s}$$

$$L_n = \sqrt{D_n \tau_n} = 4,068 \cdot 10^{-3} \text{ s}$$

$$I_s = 1,35 \cdot 10^{-14} \text{ A}$$

$$I_D = 4,863 \cdot 10^{-6} \text{ A}$$

μA

VJ. 11.

$$N_D = 10^{16} \text{ cm}^{-3}$$

$$N_A = 5 \cdot 10^{19} \text{ cm}^{-3}$$

$$\mu_n = 500 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 350 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,4 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 0,2 \cdot 10^{-6} \text{ s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 300 \text{ K}$$

$$W_n = 2 \cdot 10^{-4} \text{ cm}$$

$$L_n \ll W_p$$

$$U = 0,5 \text{ V}$$

$$m = 1$$

$$I_s, I_D = ?$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{L_n} + D_p \frac{p_{op}}{W_n} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 420,5 \text{ cm}^{-3}$$

$$p_{op} = \frac{n_i^2}{N_D} = 2,1 \cdot 10^4 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 12,93 \text{ cm}^2/\text{s}$$

$$D_p = U_T \mu_p = 9,05 \text{ cm}^2/\text{s}$$

$$L_n = \sqrt{D_n \tau_n} = 2,274 \cdot 10^{-3} \text{ cm}$$

$$I_s = 1,524 \cdot 10^{-13} \text{ A}$$

$$I_D = I_s \left(e^{\frac{U}{mU_T}} - 1 \right)$$

$$I_D = 3,8 \cdot 10^{-5} \text{ A}$$

V1.12

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$N_A = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$\mu_n = 500 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 300 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,5 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 10^{-6} \text{ s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 300 \text{ K}$$

$$L_p \ll W_n$$

$$W_p = 10^{-4} \text{ cm}$$

$$U = 0,5 \text{ V}$$

$$m = 1$$

$$I_s, I_D = ?$$

$$n_i = 1,45 \cdot 10^{10} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{N_D} + D_p \frac{p_{op}}{N_A} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 420,5 \text{ cm}^{-3}$$

$$p_{op} = \frac{n_i^2}{N_D} = 42050 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 12,93 \text{ cm}^2/\text{s}$$

$$D_p = U_T \mu_p = 7,759 \text{ cm}^2/\text{s}$$

$$L_p = \sqrt{D_p \tau_p} = 2,785 \cdot 10^{-3} \text{ cm}$$

$$I_s = 2,74 \cdot 10^{-14} \text{ A}$$

$$I_D = I_s \left(e^{\frac{U}{m U_T}} - 1 \right)$$

$$I_D = 6,84 \cdot 10^{-6} \text{ A}$$

$$\mu\text{A}$$

V1.13

$$N_D = 5 \cdot 10^{15} \text{ cm}^{-3}$$

$$N_A = 5 \cdot 10^{17} \text{ cm}^{-3}$$

$$\mu_n = 400 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 250 \text{ cm}^2/\text{Vs}$$

$$\tau_n = 0,5 \cdot 10^{-6} \text{ s}$$

$$\tau_p = 10^{-6} \text{ s}$$

$$S = 0,1 \cdot 10^{-2} \text{ cm}^2$$

$$T = 350 \text{ K}$$

$$L_p \ll W_n$$

$$W_p = 10^{-4} \text{ cm}$$

$$U = 0,5 \text{ V}$$

$$m = 1$$

$$n_i = 4,96 \cdot 10^{11} \text{ cm}^{-3}$$

$$I_s = qS \left(D_n \frac{n_{op}}{N_D} + D_p \frac{p_{op}}{N_A} \right)$$

$$n_{op} = \frac{n_i^2}{N_A} = 4,93 \cdot 10^5 \text{ cm}^{-3}$$

$$p_{op} = \frac{n_i^2}{N_D} = 4,92 \cdot 10^7 \text{ cm}^{-3}$$

$$D_n = U_T \mu_n = 12,07 \text{ cm}^2/\text{s}$$

$$D_p = U_T \mu_p = 7,54 \text{ cm}^2/\text{s}$$

$$L_p = \sqrt{D_p \tau_p} = 2,75 \cdot 10^{-3} \text{ cm}$$

$$I_s = 3,11 \cdot 10^{-11} \text{ A}$$

$$I_D = I_s \left(e^{\frac{U}{m U_T}} - 1 \right)$$

$$I_D = 4,89 \cdot 10^{-4} \text{ A} = 0,489 \text{ mA}$$

VJ 14.

$$I_s = 10^{-11} \text{ A}$$

$$r_{s1} = 5 \Omega$$

$$r_{s2} = 10 \Omega$$

$$I_D = 10^{-2} \text{ A}$$

$$T = 300 \text{ K}$$

$$U = ?$$

$$I_D = I_s \left(e^{\frac{U_D}{U_T}} - 1 \right)$$

$$\Rightarrow U_D = U_T \ln \left(\frac{I_D}{I_s} + 1 \right)$$

$$U_D = 0,536 \text{ V}$$

$$U = U_D + I_D \cdot R_s$$

$$U = 0,536 + 10^{-2} (5 + 10) = 0,686 \text{ V}$$

VJ 15.

$$T = 300 \text{ K}$$

$$I_s = 10^{-9} \text{ A}$$

$$r_{s1} = 5 \Omega$$

$$r_{s2} = 10 \Omega$$

$$I_D = 10^{-2} \text{ A}$$

$$U = ?$$

$$U_D = U_T \ln \left(\frac{I_D}{I_s} + 1 \right)$$

$$U_D = 0,486 \text{ V}$$

$$U = U_D + I_D \cdot R_s$$

$$U = 0,636 \text{ V}$$

$$[R_s = r_{s1} + r_{s2}]$$

VJ 16.

$$I_s = 10^{-11} \text{ A}$$

$$R_s = 15 \Omega$$

$$I_D = 1,5 \cdot 10^{-3} + 0,25 \cdot 10^{-3} \sin(\omega t) \text{ [A]}$$

$$T = 300 \text{ K}$$

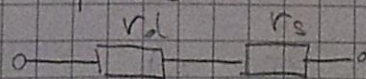
$$I_D = 1,5 \cdot 10^{-3} \text{ A}$$

$$i_d = 0,25 \cdot 10^{-3} \text{ A}$$

$$U_D = U_T \ln \left(\frac{I_D}{I_s} + 1 \right) = 0,487 \text{ V}$$

$$U = U_D + I_D R_s = 0,509 \text{ V}$$

izm signal



$$r_d = \frac{U_T}{I_s + I_D}$$

$$I_D \gg I_s \Rightarrow r_d = \frac{U_T}{I_D} = 17,24 \Omega$$

$$u_d = i_d (r_d + R_s) = 8,06 \cdot 10^{-3} \text{ V}$$

$$U_D = U + u_d \sin(\omega t) = 0,509 + 8,06 \cdot 10^{-3} \sin(\omega t) \text{ [V]}$$

VJ. 17.

$$I_s = 10^{-11} \text{ A}$$

$$R_s = 12 \Omega$$

$$I_D = 2,5 \cdot 10^{-3} \text{ A}$$

$$i_d = 0,35 \cdot 10^{-3} \text{ A}$$

$$i_D = 2,5 + 0,35 \sin(\omega t) \text{ [mA]}$$

$$T = 300 \text{ K}$$

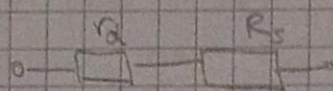
$$U_D = ?$$

$$U = U_D + I_D \cdot R_s$$

$$U_D = U_T \ln\left(\frac{I_D}{I_s} + 1\right) = 0,5 \text{ V}$$

$$U = 0,53 \text{ V}$$

Izmjenični signal.



$$r_d = \frac{U_T}{I_D + I_s}$$

$$I_s \ll I_D \Rightarrow r_d = \frac{U_T}{I_D} = 10,34 \Omega$$

$$u_d = i_d (r_d + R_s) = 7,82 \cdot 10^{-3} \text{ V}$$

$$u_D = 0,53 + 7,82 \cdot 10^{-3} \sin(\omega t) \text{ [V]}$$

W. 18.

$$U = 65 \cdot 10^{-3} \text{ V}$$

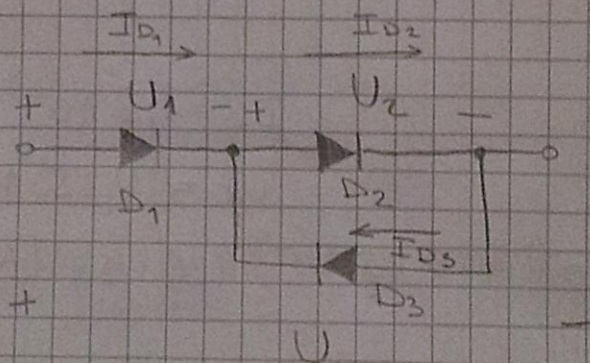
$$I_{s1} = I_{s2} = 10^{-11} \text{ A} = I_s$$

$$I_{s3} = 2 \cdot 10^{-11} \text{ A}$$

$$U_T = 25 \cdot 10^{-3} \text{ V}$$

$$m = 1$$

$$U_1, U_2 = ?$$



$$I_{D1} = I_{s1} \left(e^{\frac{U_1}{U_T}} - 1 \right)$$

$$I_{D2} = I_{s2} \left(e^{\frac{U_2}{U_T}} - 1 \right)$$

$$I_{D3} = I_{s3} \left(e^{\frac{-U_2}{U_T}} - 1 \right)$$

$$U = U_1 + U_2 \Rightarrow U_1 = U - U_2$$

$$I_{D1} - I_{D2} + I_{D3} = 0$$

$$I_{D1} + I_{D3} = I_{D2}$$

$$e^{\frac{U}{U_T}} - \frac{1}{U_T}$$

$$I_s \left(e^{\frac{U - U_2}{U_T}} - 1 \right) + I_{s3} \left(e^{-\frac{U_2}{U_T}} - 1 \right) = I_s \left(e^{\frac{U_2}{U_T}} - 1 \right) \quad | : I_s$$

$$e^{\frac{U}{U_T}} \cdot e^{-\frac{U_2}{U_T}} = 1 + 2e^{-\frac{U_2}{U_T}} - 2 = e^{\frac{U_2}{U_T}} \quad | \cdot e^{\frac{U_2}{U_T}}$$

$$e^{\frac{U}{U_T}} + 2 - 2e^{\frac{U_2}{U_T}} = \left(e^{\frac{U_2}{U_T}} \right)^2$$

$$\left(e^{\frac{U_2}{U_T}} \right)^2 + 2e^{\frac{U_2}{U_T}} - 15.46 = 0$$

$$e^{\frac{U_2}{U_T}} = x$$

$$x^2 + 2x - 15.46 = 0$$

$$x_1 = 3.05$$

$$x_2 = -5.05$$

$$e^{\frac{U_2}{U_T}} = 3.05$$

$$U_2 = U_T \ln(3.05)$$

$$U_2 = 0.028 \text{ V} = 28 \text{ mV}$$

$$U_1 = 37 \text{ mV}$$