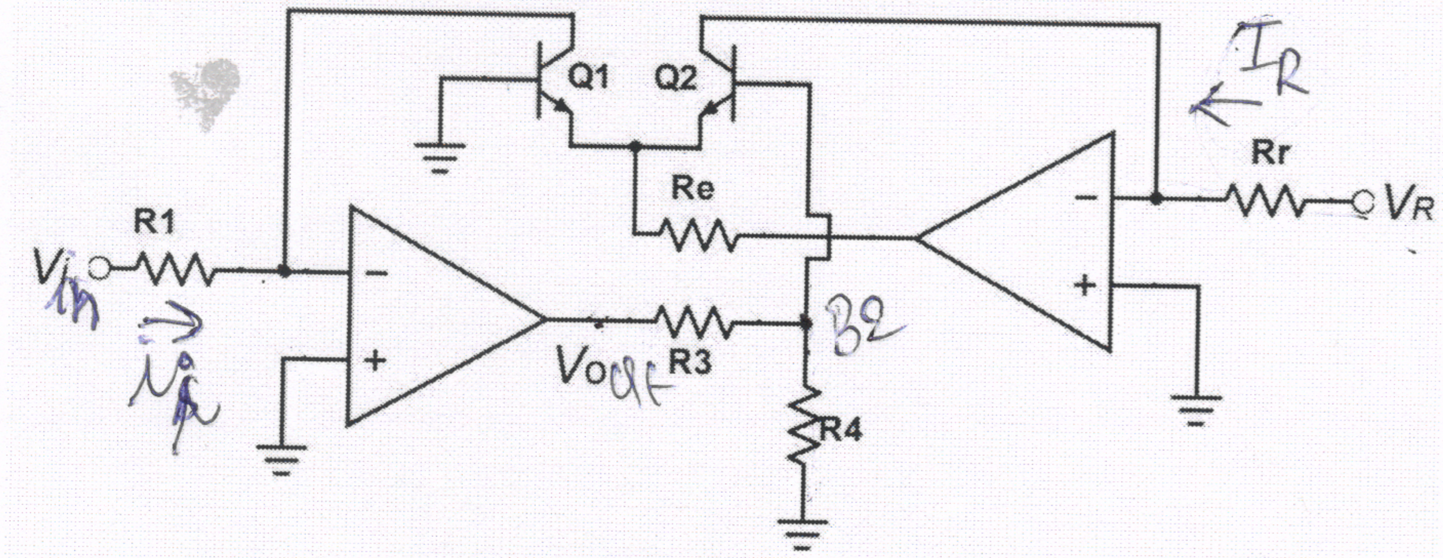
1) Na slici je prikazan logaritamski konvertor. Izlazni napona operacionog pojačavača može da se kreće u opsegu od -10V do +10V. Potrebno je realizovati logaritamski pojačavač čiji je logaritamski nagiv 2 V/dek i čija je ulazna otpornost Rin=1 kΩ. Odrediti elemente kola ukoliko se vrednost ulaznog napona kreće u opsegu od 1 mV do 10V.



$$V_{BE1} = V_T \ln \frac{i_{c1}}{I_{S1}} = V_T \ln \frac{i_{in}}{I_{S1}} = V_T \ln \frac{V_{in}}{R_1 I_{S1}}$$

$$V_{BE2} = V_T \ln \frac{i_{c2}}{I_{S2}} = V_T \ln \frac{I_R}{I_{S2}} = V_T \ln \frac{V_R}{R_r \cdot I_{S2}}$$

$$V_{B2} = V_{BE2} - V_{BE1} = V_T \ln \frac{V_R}{R_r I_S} \cdot \frac{R_1 I_S}{V_{in}}$$

$$V_{B2} = V_{out} \cdot \frac{R_4}{R_3 + R_4}$$

$$V_{out} = \left(1 + \frac{R_3}{R_4}\right) \cdot V_T \ln \frac{V_R \cdot R_1}{R_r V_{in}}$$

$$V_{out} = -\left(1 + \frac{R_3}{R_4}\right) \cdot V_T \cdot \ln \frac{V_{in} R_r}{V_R \cdot R_1}$$

$$\ln x = \frac{\log x}{\log e} = \log x \cdot 2{,}303$$

$$\boxed{V_{out} = -\left(1 + \frac{R_3}{R_4}\right) \cdot V_T \cdot 2{,}303 \cdot \log \frac{V_{in} R_r}{V_R \cdot R_1}}$$

$$V_{out} = K \cdot \log \frac{V_{in} R_r}{V_R \cdot R_4}$$

$$K = \left(1 + \frac{R_3}{R_4}\right) \cdot V_T \cdot 2{,}303 = 2 \frac{V}{dek}$$

$$\frac{R_3}{R_4} = \frac{2}{0.026 \cdot 2{,}303} - 1$$

$$\frac{R_3}{R_4} = 32{,}4$$

$$R_1 = 1K\Omega$$

3a $V_{in}' = 1mV$ $\quad V_o' = 10V$

3a $V_{in}'' = 10V$ $\quad V_o'' = -10V$

$$\frac{V_o'}{V_o''} = -1 = \frac{K \log \frac{V_{in}' R_r}{V_R \cdot R_1}}{K \cdot \log \frac{V_{in}'' \cdot R_r}{V_R \cdot R_1}}$$

$$\log \frac{V_{in}' \cdot R_r}{V_R \cdot R_1} + \log \frac{V_{in}'' R_r}{V_R \cdot R_1} = 0$$

$$\log \frac{V_{in}' \cdot V_{in}'' \cdot R_r^2}{V_R^2 R_1^2} = 0$$

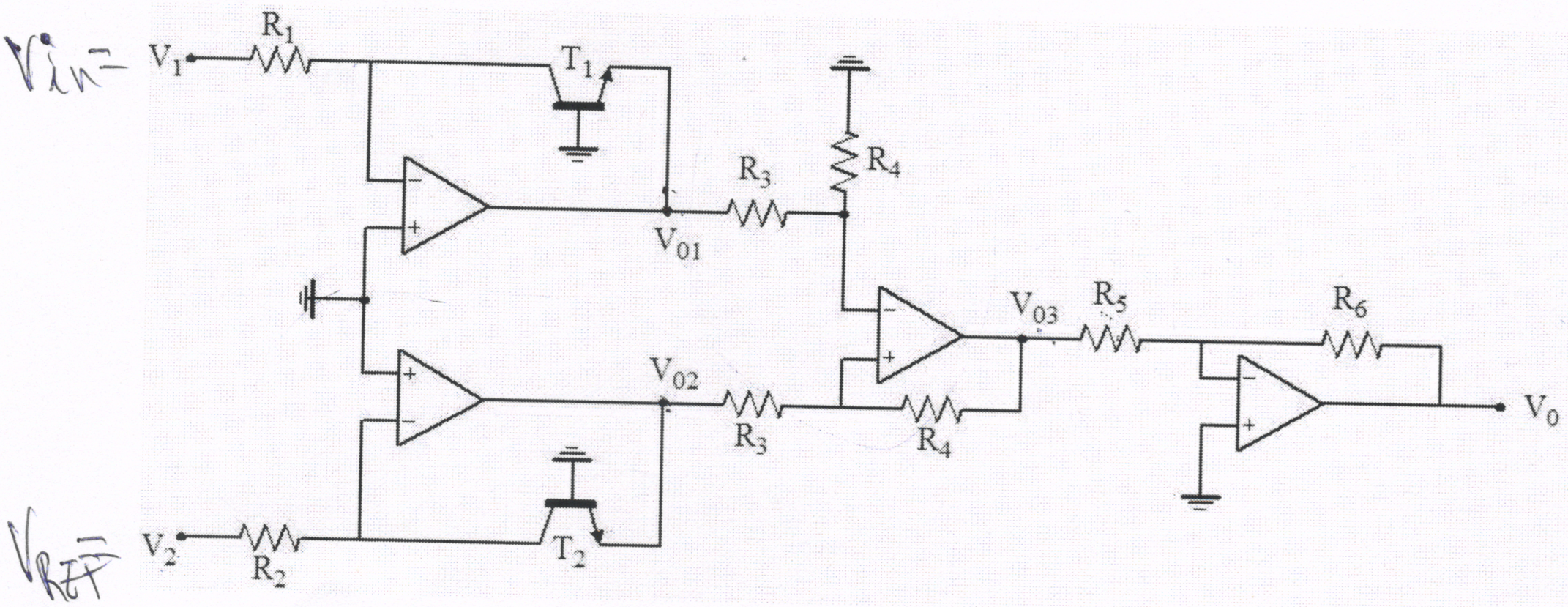
$$\frac{V_R}{R_r} = \sqrt{\frac{V_{in}' V_{in}''}{R_1^2}} = \sqrt{\frac{10^{-3} \cdot 10}{10^6}} = 10^{-4} A$$

$I_R = 100 \mu A$ $\quad \frac{V_R}{R_r} = 100 \mu A$

2) U kolu diferencijalnog logaritamskog pojačavača sa slike poznati su elementi kola: R_1=2 kΩ, R_2=10 kΩ, V_2=5 V, R_3=R_4=10kΩ.

A) Odrediti otpornike R_5 i R_6 tako da logaritamski nagib iznosi k=1 V/dek

B) Izvršiti temperatursku kompenzaciju kola pomoću termistora vezanog na red sa R5. Temperaturni koeficijent termistora je 6000 ppm/°C.



$$V_{01} = -V_{BE1} = -V_T \ln \frac{V_1}{R_1 I_S}$$

$$V_{02} = -V_{BE2} = -V_T \ln \frac{V_2}{R_2 I_S}$$

$$V_{03} = \frac{R_4}{R_3+R_4} \cdot \frac{R_3+R_4}{R_3} \cdot V_{01} - \frac{R_4}{R_3} V_{02}$$

$$V_{03} = +\frac{R_4}{R_3}(V_{02} - V_{01})$$

$$V_{03} = +\frac{R_4}{R_3} \cdot V_T \left(\ln \frac{V_2}{R_2 I_S} + \ln \frac{V_1}{R_1 I_S} \right)$$

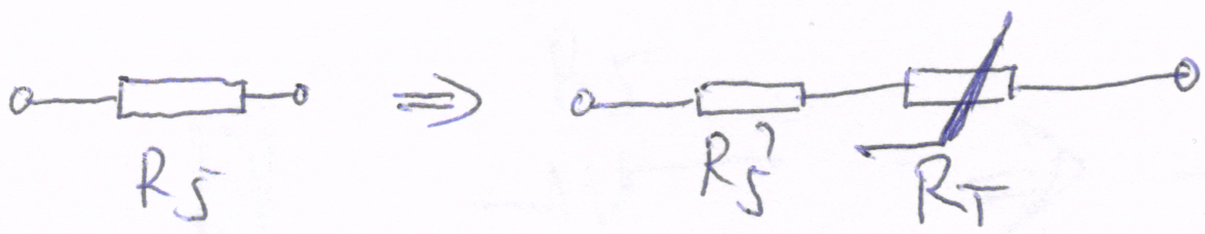
$$V_{03} = \frac{R_4}{R_3} \cdot V_T \cdot \ln \left(\frac{V_1}{R_1 I_S} \cdot \frac{R_2 I_S}{V_2} \right)$$

$$V_0 = -\frac{R_6}{R_5} \cdot \frac{R_4}{R_3} V_T \cdot \ln\left(\frac{V_1 R_2}{R_1 V_2}\right)$$

$$V_0 = -\frac{R_6}{R_5} \cdot \frac{R_4}{R_3} V_T \cdot 2{,}303 \cdot \log \frac{V_2 R_2}{R_1 V_2}$$

$$K = \frac{R_6}{R_5} \cdot \frac{R_4}{R_3} \cdot V_T \cdot 2{,}303 = 1 \frac{V}{\Delta K}$$

$$\frac{R_6}{R_{T5}} = \frac{1}{2{,}303 \cdot 0{,}026} = 16{,}7$$

b) 

$$TCR_T = \frac{1}{R_T} \frac{\partial R_T}{\partial T} = 6000 \frac{ppm}{°C} = 6 \cdot 10^{-3} \frac{1}{°C}$$

$$V_0 = -\frac{R_6}{R_5' + R_T} \cdot \frac{R_4}{R_3} \cdot V_T \cdot 2{,}303 \cdot \log \frac{V_1 R_2}{R_1 R_2}$$

$V_0(T) = A \cdot \frac{V_T}{R_5' + R_T}$ A - константа чиниоца која се разматра зависности од температуре

$$\frac{dV_0}{dT} = A \cdot \frac{\frac{dV_T}{dT}(R_5' + R_T) - \frac{dR_T}{dT} \cdot V_T}{(R_5' + R_T)^2}$$

$$\frac{dV_0}{dT} = 0 \Rightarrow \frac{dV_T}{dT} \cdot (R_5' + R_T) - \frac{dR_T}{dT} \cdot V_T = 0$$

$$\frac{dV_T}{dT} = \frac{V_T}{T} = K \cdot 2$$

$$\frac{V_T}{T} \cdot (R_5' + R_T) - TCR_T \cdot R_T \cdot V_T = 0$$

$$R_5' = R_T (TCR_T \cdot T - 1)$$

$$R_5' = R_T \cdot (6 \cdot 10^{-3} \cdot 300 - 1) = 0{,}8 \cdot R_T$$

$$R_5' = 0{,}8 R_T$$

$$R_5' + R_T = R_5$$