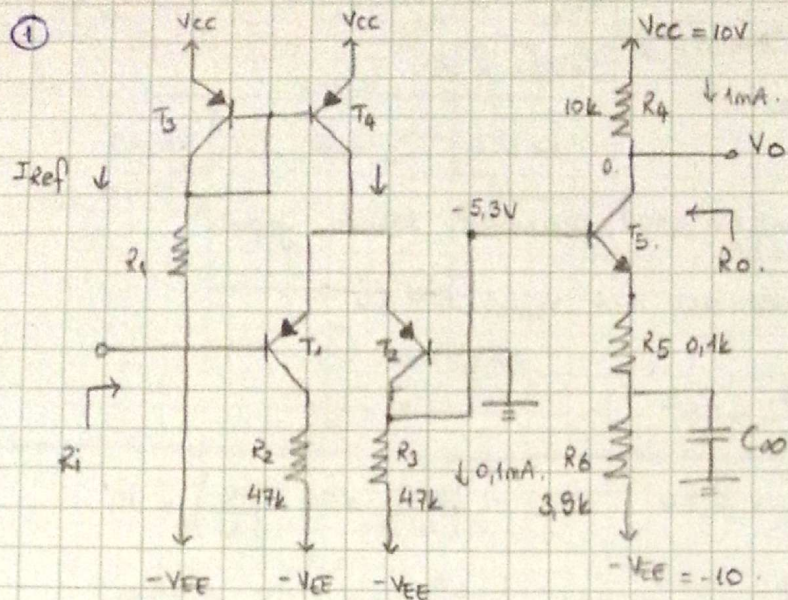


①



$$\beta_f = 300$$

$$V_A = 50 \text{ V} \quad V_{BE} = 0.7 \text{ V}$$

$$V_{CEsat} = 0.3 \text{ V}, \quad V_T = 26 \text{ mV}$$

$$T_1 - T_2, T_3 - T_4 \text{ eşit}$$

a)  $I_{C5} = 1 \text{ mA}, \quad V_{B5} = -5.3 \text{ V}$

$$-5.3 - (-10) = (I_{C2} - \frac{1 \text{ mA}}{300}) \cdot 47 \text{ k}$$

$$0.1 \text{ mA}$$

$$I_{C1} + I_{C2} = I_{ref} \approx 0.207 \text{ mA}$$

$$10 - 0.7 - (0.207 \text{ mA}) \cdot R_1 = -10$$

$$0.207 \text{ mA} \cdot R_1 = 19.3$$

$$I_{C2} = 0.103 \text{ mA} = I_{C1}$$

$$R_1 = 93.2 \text{ k}$$

b)  $\frac{V_o}{V_i} = \frac{V_{C2}}{V_i} \cdot \frac{V_o}{V_{C2}} = \left( \frac{R_3 \parallel r_{o2} \parallel r_{i5}}{2r_{e2}} \right) \left( \frac{-R_4 \parallel r_{o5}}{r_{e5} + R_5} \right)$

Fark Kuvv. CE Amp.

$$r_{o2} = \frac{V_A}{I_{C2}} = 483 \text{ k}$$

$$r_{e2} = \frac{V_T}{I_{E2}} \approx 0.25 \text{ k} \quad r_{e5} \approx 26 \text{ } \Omega$$

$$r_{o5} = \frac{V_A}{I_{C5}} = 50 \text{ k}$$

$$r_{i5} = \beta_f (r_{e5} + R_5) = 300 \cdot (26 + 100) = 37.8 \text{ k}$$

$$\frac{V_o}{V_i} = \left( \frac{47 \text{ k} \parallel 483 \text{ k} \parallel 37.8 \text{ k}}{0.5 \text{ k}} \right) \cdot \left( \frac{-10 \text{ k} \parallel 50 \text{ k}}{0.126 \text{ k}} \right) = 40.13 \times (-66.14) \Rightarrow \frac{V_o}{V_i} = -2654.2$$

$$R_i = 2 \cdot \beta_f r_{e2} = 2 \cdot 300 \cdot 250 = 150 \text{ k} = R_i$$

$$R_o = R_{o3} \parallel R_4$$

$$R_{o5} = r_{o5} \cdot \frac{\beta_f (R_5 + r_{e5}) + R_3}{\beta_f r_{e5} + R_3} = 50 \text{ k} \cdot \frac{300 (100 + 26) + 47 \text{ k}}{300 \cdot 26 + 100 + 47 \text{ k}} = 77.23 \text{ k}$$

$$R_o = 77.23 \text{ k} \parallel 10 \text{ k} \approx 8.85 \text{ k}$$



d) AC çevrim;

$$V_{CC} = I_C \cdot (R_4 + R_5) + V_{CEsat} - V_{EE}$$

$$I_C = \frac{20 - 0,3}{10,1k} = 1,95 \text{ mA}$$

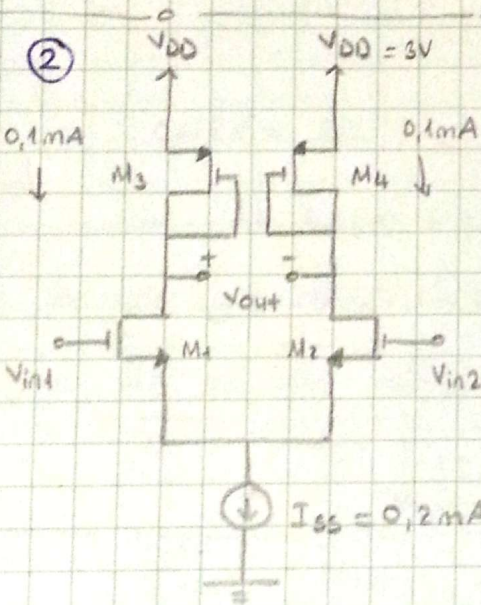
$$V_{min} = V_{CC} - R_4 \cdot I_C = 10 - 10k \cdot 1,95 = -9,5 \text{ V}$$

$$V_{omax} = 10 \text{ V}$$

Bu sonuçlarla çıkış gerilimi  $-9,5 \text{ V} - 10 \text{ V}$  arasında salınım yapar.

Çıkış işaretinde kırılma olmaması için  $V_{omax} = 9,5 \text{ V}$

$$V_{imax} = \frac{9,5}{2564} \approx 3,5 \text{ mV}$$



$$V_{tn} = 0,7 \text{ V}$$

$$V_{tp} = -0,8 \text{ V}$$

$$\mu_n \cdot C_{ox} = 135 \text{ } \mu\text{A/V}^2$$

$$\mu_p \cdot C_{ox} = 45 \text{ } \mu\text{A/V}^2$$

$$I_{SS} = 0,2 \text{ mA}$$

$$\left(\frac{W}{L}\right)_n = 30 \quad \left(\frac{W}{L}\right)_p = 10$$

$$R_{SS} = 100k$$

$$a) A_d = \frac{V_{o1} - V_{o2}}{V_{i1} - V_{i2}}$$

$$I_{D1} = I_{D2} = 0,1 \text{ mA}$$

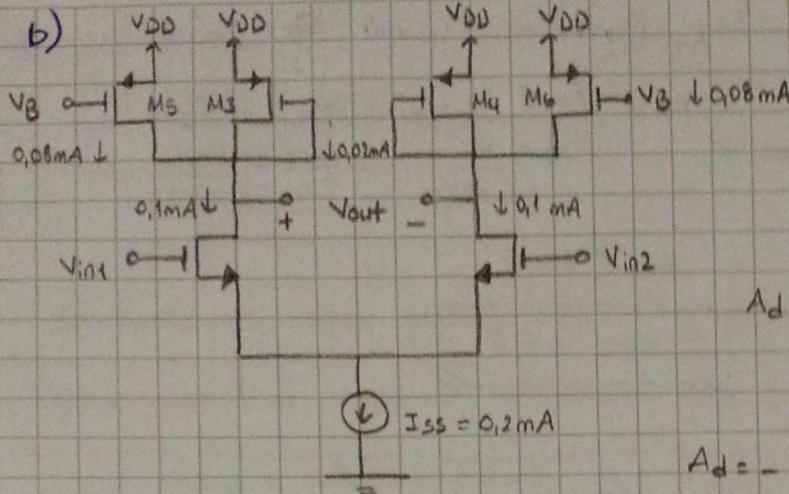
$$A_d = \frac{-g_{m1}}{g_{m3}} = - \frac{\sqrt{2 \cdot \mu_n \cdot C_{ox} \cdot \left(\frac{W}{L}\right)_1 \cdot I_{D1}}}{\sqrt{2 \cdot \mu_p \cdot C_{ox} \cdot \left(\frac{W}{L}\right)_3 \cdot I_{D2}}} = -3 //$$

$$A_{cm} = \frac{\frac{1}{g_{m3}}}{2R_{SS} + \frac{1}{g_{m1}}} = \frac{-g_{m1}}{g_{m3}} \cdot \frac{1}{2R_{SS}g_{m1} + 1} = A_d \cdot \frac{1}{2R_{SS}g_{m1} + 1}$$

$$g_{m1} = \sqrt{2 \cdot \mu_n \cdot C_{ox} \cdot \left(\frac{W}{L}\right)_1 \cdot I_{D1}} = 0,9 \text{ mS}$$

$$CMRR = 20 \cdot \log \left| \frac{A_d}{A_{cm}} \right| = 20 \cdot \log (2R_{SS} \cdot g_{m1} + 1) = 20 \cdot \log (181) \quad \boxed{CMRR = 45,15 \text{ dB}}$$





$$I_{D1} = I_{D2} = 0.1 \text{ mA}$$

$$I_{D3} = I_{D4} = 0.02 \text{ mA}$$

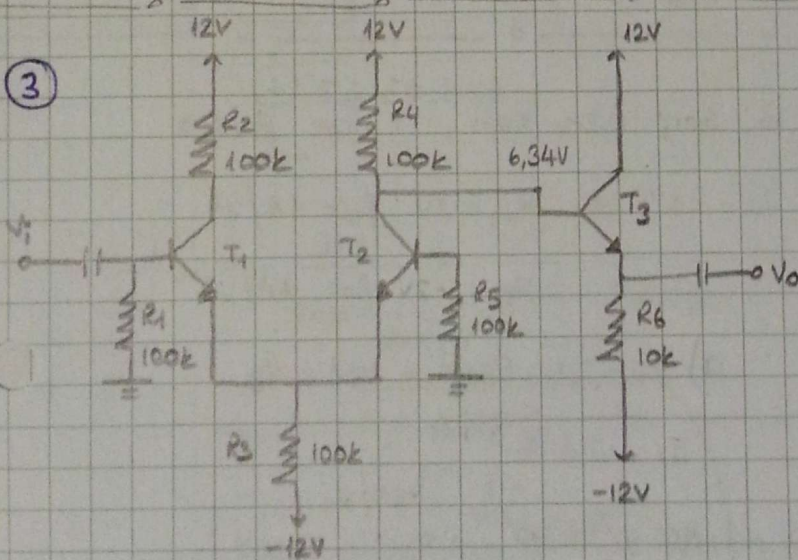
$$I_{D5} = I_{D6} = 0.08 \text{ mA}$$

$$A_d = \frac{V_{o1} - V_{o2}}{V_{i1} - V_{i2}} = \frac{-g_{m1}}{g_{m3}}$$

$$A_d = - \frac{\sqrt{2 \cdot \mu_n \cdot C_{ox}} \cdot \left(\frac{W}{L}\right)_1 \cdot I_{D1}}{\sqrt{2 \cdot \mu_p \cdot C_{ox}} \cdot \left(\frac{W}{L}\right)_3 \cdot I_{D3}} = - \sqrt{3 \cdot 3 \cdot 5} = -6.71$$

$$CMRR = 20 \cdot \log \left| \frac{A_d}{A_{cm}} \right| = 20 \cdot \log (2 R_{SS} \cdot \underbrace{g_{m1}}_{\text{sbt.}} + 1) \rightarrow \text{değişmez.}$$

c) Devrede yük olarak aktif eleman kullanılmıştır. Zaten avantajlı olan topolojiye M5 ve M6 eklenerek  $g_{m3}$  azaltılmış fakat işaret kazancı artırılmıştır.



$$\beta = 200, V_T = 25 \text{ mV}, V_{BE1} = V_{BE2} = 0.6 \text{ V}, V_{BE3} = 0.7 \text{ V}$$

$$a) 0 - 100k \cdot I_{B1} - 0.6 - 100k \cdot 402 I_{B1} = -12 \text{ V}$$

$$11.4 = 100k \cdot 403 \cdot I_{B1}$$

$$I_{B1} = 2.82 \cdot 10^{-7}$$

$$I_{C1} = 56.6 \mu\text{A} = I_{C2}$$

$$V_{E2} = 12 - 100k \cdot 56.6 \cdot 10^{-6} = 6.34 \text{ V} = V_{B3}$$

$$V_{E3} = 5.64 \text{ V}$$

$$\frac{5.64 - (-12)}{10k} \approx I_{C3} = 1.67 \text{ mA}$$



$$b) r_{e3} = \frac{V_T}{I_{c3}} = 15 \Omega$$

Fark Kuvvetlendiricisinin Ger. Kazancı;

$$K_{v2} = \frac{R_4 \parallel r_{i3}}{2r_{e2} + \frac{R_5}{\beta}} = \frac{(100k \parallel 2002k)}{2.442 + \frac{100k}{200}}$$

$$K_{v2} \approx 68,8$$

$$\boxed{\sum K_v = 68,8}$$

$$\sum K_v = \underbrace{K_{v1}}_{\text{Fark Kuv.}} \cdot \underbrace{K_{v2}}_{\text{Emetör Çıkışlı Devre (Kazanç 1.)}}$$

$$r_{i3} = \beta \cdot (r_{e3} + R_6) \approx 2002k$$

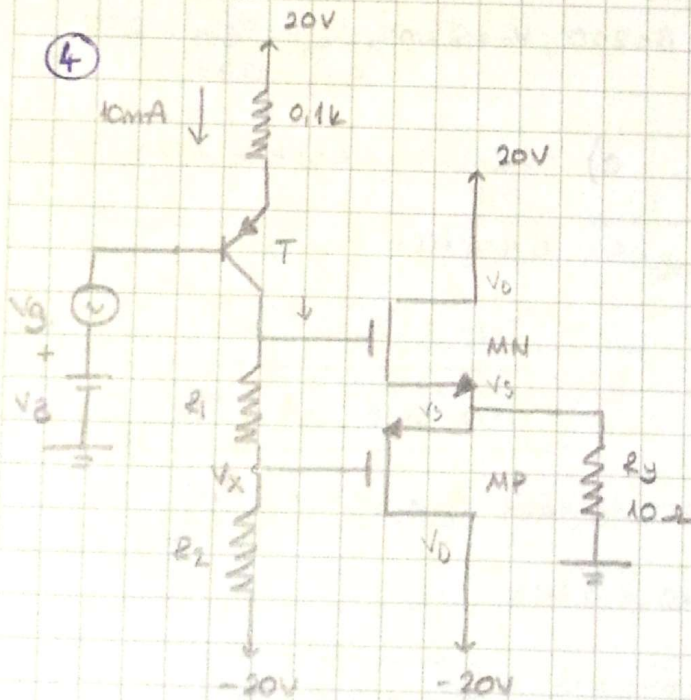
$$c) r_i = R_1 \parallel r_{i1}' \quad r_{i1}' = 2 \cdot \beta \cdot r_{e1} + R_5 = 276,8k$$

$$r_i = 100k \parallel 276,8k \Rightarrow \boxed{r_i = 73,46k}$$

$$r_o = R_6 \parallel r_{o3}' \quad r_{o3}' = r_{e3} + \frac{R_4}{\beta} = 14,9 + \frac{100k}{200}$$

$$r_{o3}' = 515 \Omega$$

$$r_o = 10k \parallel 515 \Rightarrow \boxed{r_o = 489,6 \Omega}$$



3 Sınıf Çıkış Katı, T için  $\beta = 100$

$$I_s = 10^{-14} A \quad V_{tn} = 2V \quad \beta_n = 1A/V^2$$

$$V_{tp} = -2V \quad \beta_p = 1A/V^2$$

$$a) 20 - 0,1k \cdot 10mA - V_{EB} = V_B$$

$$I_c = I_s \cdot e^{\frac{V_{BE}}{V_T}}$$

$$10 \cdot 10^{-3} = 10^{-14} \cdot e^{\frac{V_{BE}}{V_T}}$$

$$10^{12} = e^{\frac{V_{BE}}{V_T}}$$

$$27,63 = \frac{|V_{BE}|}{V_T}, \quad V_T = 26mV \text{ alınırsa;}$$

$$|V_{BE}| = 0,72V \text{ bulunur}$$

$$20 - 1 - 0,72 = V_B$$

$$\boxed{V_B = 18,28V}$$



€ b)  $R_y$ 'den akım akmaması:  $V_o = 0$

1. transistor için:  $V_{GS_1} = 2V$

$$V_{SG_2} = -2V.$$

$$V_{G7} = -20 + 10m \cdot (R_1 + R_2) = 2V \text{ olmak.}$$

$R_1 - R_2$  arasında bir X noktası:  $V_X = V_{GP}$ . PMOS için  $V_{SG} = -2$  olmak. ( $V_X$ )

$R_1$  direncinin üzerine 4V gerilim düşmeli.

$$R_1 = \frac{4}{10m} = \underline{0,4k}$$

€ 
$$R_2 = \frac{-2 - (-20)}{10m} = \frac{18}{10m} = \underline{1,8k}$$