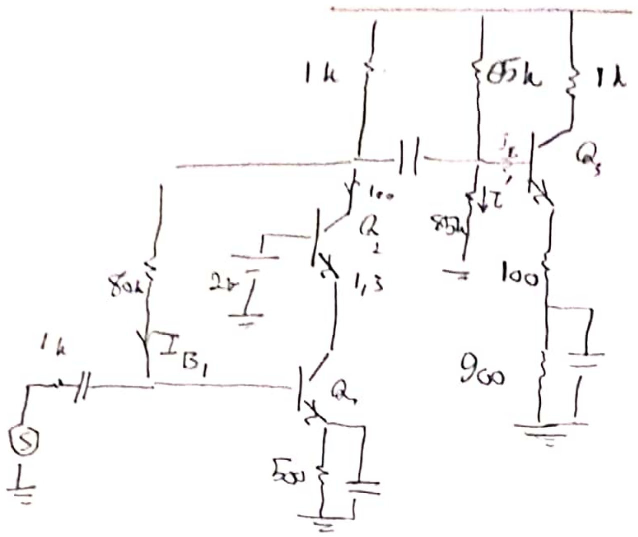
سوال 4.



الف)

$$I_{C_1} = I_{E_2} \simeq I_{C_2}$$

$$3v - (101) I_B \times 1k - 80k\, I_B - .7 - .5 \times (101) I_B = 0$$

$$I_{B_2} = I_{B_1} = 9{,}9 \times 10^{-3} \rightarrow I_{C_1} = I_{C_2} \simeq 1mA$$

$$V_{CE_2} = 3 - 1k \times 1mA = 2v - 1{,}3 = .7v$$

$$V_{CE_1} = -(3 - 1\times 1 - 80 \times .01 - .7) + 1{,}3 = .8v$$

Q_1: $I_{C_1} = 1mA$, $V_{CE_1} = .8v$, $g_{m_1} = 40m℧$, $r_{\pi_1} = 2{,}5k\Omega$

Q_2: $I_{C_2} = 1mA$, $V_{CE_2} = .7v$, $g_{m_2} = 40m℧$, $r_{\pi_2} = 2{,}5k$

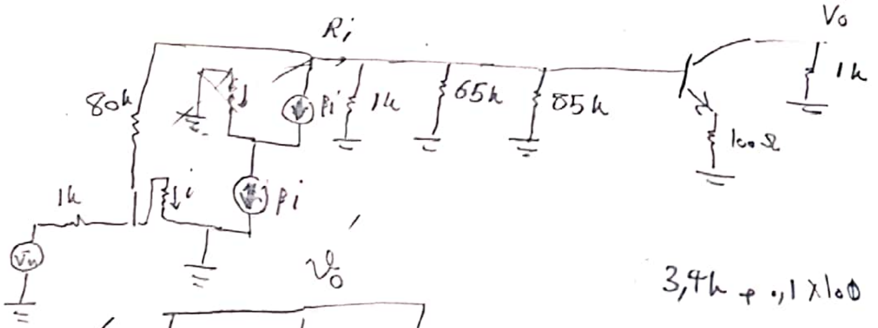
$$\begin{cases} I' 85k + 65(I' + I_{B_3}) = 3v \\ 85 I' - 101 I_B - .7 = 0 \end{cases}$$

$$\begin{cases} I' 150 + 65 I_{B_3} = 3 \\ 85 I' - 101 I_{B_3} = .7 \end{cases} \quad I' = .016{,}9 \times 10^{-3}, \quad I_B = .07{,}26 \times 10^{-3} \rightarrow I_{C_3} \simeq .73mA$$

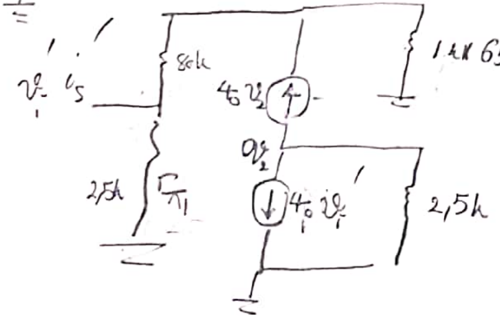
Q_3: $I_{C_3} = .73$, $V_{CE_3} = 1{,}54v$, $g_{m_3} = 29{,}2m℧$, $r_{\pi_3} = 3{,}4k\Omega$

$V_{C_{dc}} = 2v$

ب)



$$R_{out} = 1k\Omega$$



$$3{,}4k + .1 \times 100$$

$$1k \,\|\, 65k \,\|\, 85 \,\|\, (3{,}4 + .1 \times 100) = .908k$$

$$\begin{cases} \dfrac{v_o'}{.908} + \dfrac{v_o' - v_i'}{80k} - 40 v_2 = 0 \\ 40 v_i' + \dfrac{v_2}{2{,}5k} - 40 v_2 = 0 \end{cases}$$

$$\rightarrow v_i' = \frac{v_2}{1010}$$

$$v_o'\left(\frac{1}{.908k} + \frac{1}{80k}\right) = v_i'\left(\frac{1}{80k} + \frac{40m℧}{1010}\right)$$

$$\rightarrow \frac{v_o'}{v_i'} = -36$$

$$R_{in} \Rightarrow \frac{v_i}{2{,}5k} + \frac{v_i - v_o}{80k} = i_s \qquad (v_o = +36 v_i)$$

r_s 1k سری: $\xrightarrow{R_{in}} \dfrac{v_i}{i_s} = 1{,}16k\Omega$

$$A_{V_2}^{CE} = -\frac{R_C}{R_E + \frac{R_{T_2}}{\beta}} = -\frac{1\,k\Omega}{0{,}1k + \frac{3{,}4k}{100}} \approx -7{,}5$$

$$A_v = \frac{1{,}16}{1{,}16+1} \times (-36) \times -7{,}5 = 145$$

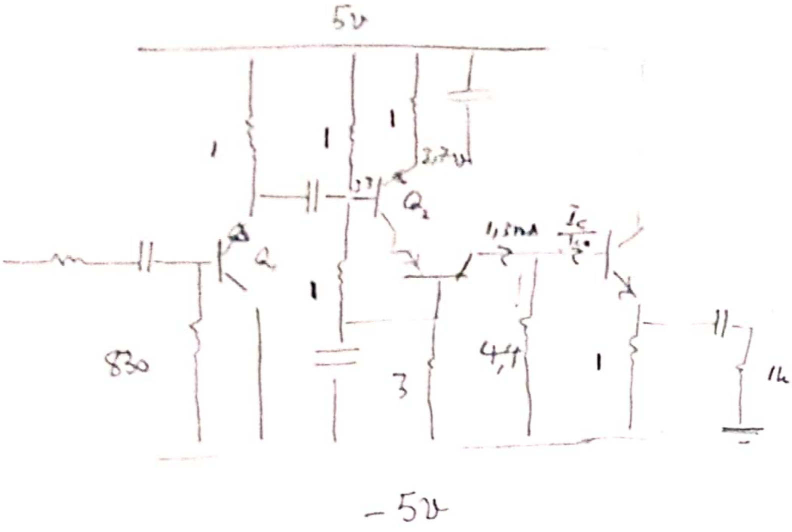
(2

$$\bar{V}_{C_{DC}} = 2v$$

$$I_{C_{DC}} = 0{,}73 = \frac{\bar{V}^+}{1k} \rightarrow \bar{V}^+ = 0{,}73v$$

$$\rightarrow \bar{V}_{P-P}\ Mos = 2 \times 0{,}73 = 1{,}46v$$

$$1{,}54v - \bar{V}^- = \frac{\bar{V}^-}{1k} \times 100 \rightarrow \bar{V}^- = 1{,}40.$$



Q_1: $5 - I_C \times 1 - .7 - \frac{I_C}{100} \times 830 = -5$ $Q_2 \& Q_3$ فرض $I_{B_2} \& I_{B_3} \ll I$

$\rightarrow 10 - .7 = 9,3 \rightarrow I_C = 1mA$

$V_{B_3} = -5 + \frac{10 \times 3}{5} = 6v = 1v$

$V_{CE} = -5 - (.5 - 1v) = -9v$ ✓

$V_{B_2} = -5 + \frac{4 \times 10}{5} = 3v$

$Q_4 = -5 - 1k\, I_{C_4} - .7 - 4,4 \times 1,3mA =$

$I_{C_2} = I_{C_3} = \frac{5 - 3,7}{1} = 1,3mA$

$-5 + (4,4)(1,3 - \frac{I_C}{100}) - .7 - I_C = -5$

$V_{CE_2} = \underbrace{(1+.7)}_{1,7} - \overbrace{(5 - 1,3)}^{3,7} = -2v$

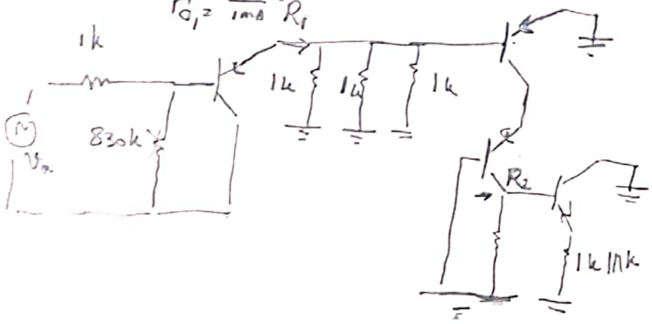
$\rightarrow I_C = 4,8\ mA$

$V_{CE_3} = -5 + 1,3 \times 4,4 - 1,7 \simeq -1v$

$V_{CE_4} = 5 - \overbrace{(-5 + 1 \times 4,8)}^{-.2} = 5,2\ v$

	Q_1	Q_2	Q_3	Q_4
	1mA	1,3mA	1,3 mA	4,8mA
	-9v	-2v	-1v	5,2 v
	40mv	52mv	52mv	192 mv
	25kΩ	1,92kΩ	1,92kΩ	520Ω

$r_{o_1} = \frac{100}{1mA} = 100k\Omega = R_1$



$R_2 = 4,4k \parallel (r_\pi + \beta(\frac{1 \parallel 1}{.5}))$

$= 4,04$

$R_{in} = (2,1k + (1+\beta) R_E) \parallel 830$ $R_i = (1k \parallel 1k \parallel 1k \parallel \frac{r_\pi}{4}) = 294\Omega$

$= 2,5 + (1+\beta) R_i = 31k\Omega$

$$A_{v_1} = \frac{R_1 \| R_{o_1}}{R_1 \| R_{o_1} + \frac{r_{\pi_1}}{\beta}} = \frac{294\,\Omega}{294\,\Omega + \frac{2{,}5}{101}} = {,}921$$

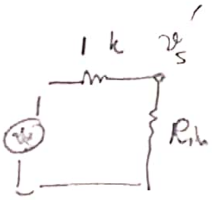
($R_1 \| R_{o_1}$: 1,9k)

Cascode

$$A_{v_2} = -\frac{R_2}{\frac{r_\pi}{\beta}} = -\frac{4k}{\frac{1{,}92k}{100}} \simeq -210$$

$$A_{v_3} = \frac{1 \| 1 \| r_o}{1\|1\|r_o + \frac{r_\pi}{100}} = \frac{500}{500 + \frac{500}{100}} = 0{,}991$$

$$\rightarrow \frac{v_o}{v_s'} = {,}92 \times -210 \times {,}99 \simeq -191$$



$$v_s' = \frac{R_{in}}{R_{in} + 1} \rightarrow A_v = -185$$

R_o

$$R_{out} = R_L \| \frac{1}{g_{m_4}} \simeq 5\,\Omega$$

2)

$$v_{+p} = 5 - {,}2 = 4{,}8\,v$$

[illegible] $\rightarrow$ $$v^- = (R_L \| R_{o4}) I_{C4} = 2{,}5\,v$$

3 $\rightarrow$

$$v_+ = 1v - {,}2v = {,}8v$$

$$v_- = R_2 I_S = 5{,}25\,v$$

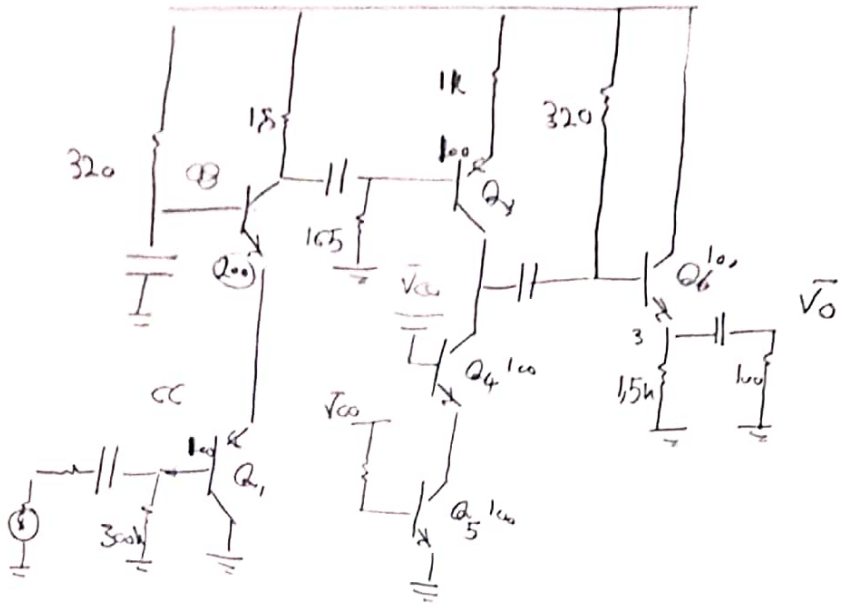
$V_{BDC} = 0$

$1 - V_+ = {,}2$

$\rightarrow V_+ = 1 - {,}2 = {,}8v$

$$\rightarrow V_{P-P} = {,}8 \times 2 = 1{,}6\,v$$

$\bar{V}_{cc}$ 6



$\bar{V}_0$

Q_6 : $6V - \frac{320 I_C}{200} - .7 - 1,5 I_C = 0$

$\rightarrow I_C = 2$

$\bar{V}_{CE6} = 6 - (6 - \frac{320}{200} 2 - .7)$

$= 3V$

$6 - 320 \times \frac{I_C}{200} - .7 + .7 + 300 \times \frac{I_C}{100} = 0$

$\rightarrow \underline{I_{C_2} = I_{C_1} = 0,1mA \; | -1mA)}$ $V_{CE_2} = 6 - 1,5 \times 1$ $= \underline{0,8 - V |}$

$\bar{V}_{C_1} = 0 - (6 - \frac{320 \times 1}{200} - .7) = \underline{-3,7 V |V}$

$6V - 1k\, I_{C_3} - .7 - \frac{I_{C_3}}{100} \times 165 = 0 \rightarrow \underline{I_{C_3} = 2,0 mA |}$

$\bar{I}_{C_4} = \bar{I}_{C_4} = 2,0 mA$

$\bar{V}_{C_3} = 2V \rightarrow \bar{V}_{CE_3} = 2V - \frac{(6 - 1 \times 2,0)}{4} = \underline{-2V |}$

Q_1 { $I = 1mA$; $-3,7V$; $40mV$; $2,5k\Omega$; $100k$

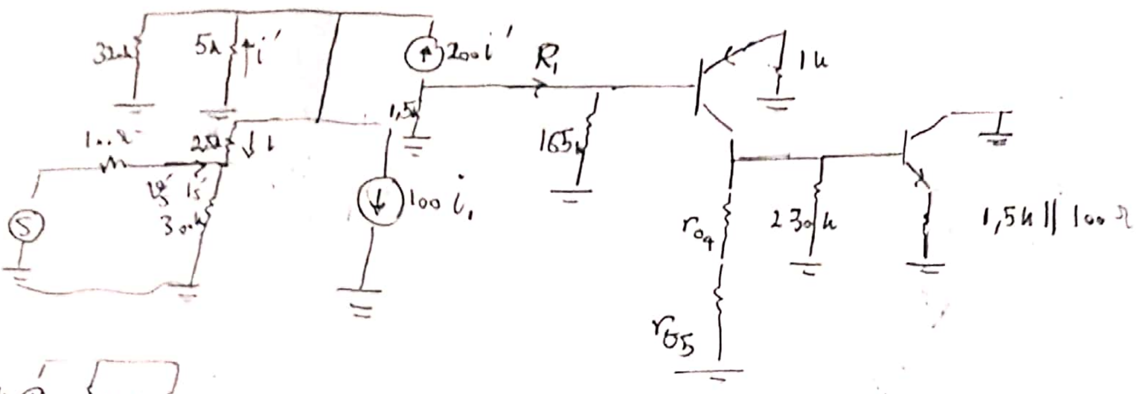
Q_2 { $1mA$; $0,8V$; $40mV$; $5k\Omega$; $100k$

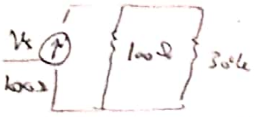
Q_3 { $2mA$; $-2V$; $80mV$; $1,25k\Omega$; $50k$

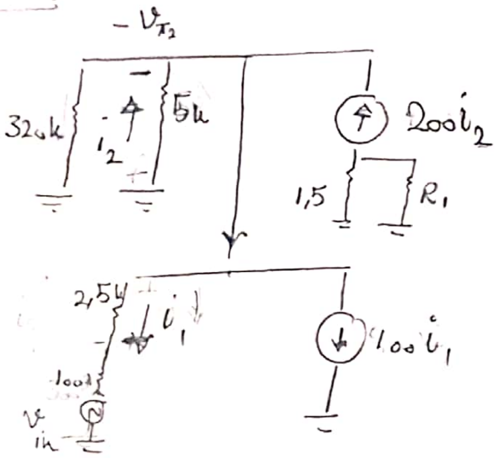
Q_4 { $2mA$; $-$; $50k$; $V_1 - 3,3$

Q_5 { $2mA$; $50k$; $53 - V_1$

Q_6 { $I_C = 2mA$; $\bar{V}_{CE_3} = 3V$; $80mV$; $2,5k$







$R_1 = 165 \parallel (r_{\pi_3} + (101)\,1k) = 102{,}25k\Omega \parallel 165$ (r_{π_3} = 1,25)

$= 63{,}1\ k\Omega$

$200 i_2 + i_2 + \frac{i_2 5}{320} = 100 i_1 + i_1$

$101\, i_1$

$v_{in} + 100 i_1 + 2{,}5 i_1 + 5 i_2 = 0 \rightarrow i_2 \approx 0{,}5\, i_1$

$\rightarrow v_{in} = -5{,}1\, i_1 \rightarrow i_1 = \frac{-v_{in}}{5{,}1} \rightarrow v_o = +(1{,}5 \parallel R_1)\, 200 \times 0{,}5 \times \frac{v_{in}}{5{,}1}$ (1,47)

$\rightarrow R_{in} = 5{,}0\ k\Omega$

$A_{v_1} = \frac{v_{o1}}{v_{in}} = 28{,}73$

$R_{out} = 1{,}5 \parallel 100\Omega \parallel \frac{1{,}25k + R_S}{101}$

$= 83\ \Omega$

$50k\,(1 + 80m\mho\,(1k \parallel 1{,}25k))$

$\rightarrow 22727\ k$

$\rightarrow 100k \parallel 230k = 69{,}7\ k\Omega$

$\rightarrow 69\ k$

$CG \rightarrow -\frac{R_C}{1k + \frac{1{,}25}{101}} = -\frac{19{,}3k}{} = -19{,}18$

$1{,}25 + (101)(1{,}5 \parallel 100\Omega) = 10{,}79$

$CC = \frac{R_E \parallel r_o}{R_E \parallel r_o + \frac{1{,}25}{100}} = 0{,}88$

$10{,}79k \parallel 100k \parallel 230k$

$\rightarrow 9{,}3\ k\Omega$

باید روش دیگری رو تا نهایتش ببریم

$r_{\pi_1} + (101) R_E$

ذیل راه دیگری محاسبه

$R_G = \frac{r_{\pi_2}}{200} = \frac{5k\Omega}{200} = 25\Omega \rightarrow R_{in} = (r_{\pi_1} + 101 \cdot 25\Omega) \| 300k = 4{,}9k$

$A_{v_1} = + \frac{R_E \| r_{\sigma_2}}{R_E \| r_{\sigma_2} + \frac{r_{\pi_1}}{\beta}} = 0{,}51$ (25Ω, 100k, 2,5, β 100)

$A_{v_2} = \frac{R_C}{R_S + \frac{5k}{200}} = \frac{R_C \| 1{,}5k}{\frac{5k}{200}} = 58{,}60$

$A_{v_3} = - \frac{R_C}{R_E + \frac{r_\pi + R_S}{\beta}} = - \frac{19{,}5}{1 + \frac{1{,}25}{100}} = -19{,}3$

$R_C = 100k \| 230k \| (2{,}5 + 200 \times 1{,}5 \| 0{,}1)$ (21,3)

$= 19{,}5k$

$AV_4 = 0{,}88$

$R_{out} = 100 \| 1{,}5k \| 12{,}5\Omega = 11\Omega$

$\rightarrow A_v = -502{,}8$

swing

چون ac طبقه آخر است باید طبقه قبل چک شود

Q_6

$3v - v^+ \geq 0{,}2 \quad v^+ = 2{,}8$

$2mA \times 10^{-3} = \frac{v^-}{94} \rightarrow v^- = 0{,}19$

Q_3

$-2 + v^+ \times 0{,}88 \leq 0{,}2 \quad v^+ \leq 1{,}8$

$2 = \frac{0{,}88 v^-}{19{,}6} \quad v^- = -44$ ✓

طبقه 3 معتبر نیست روی Q_4 و Q_5

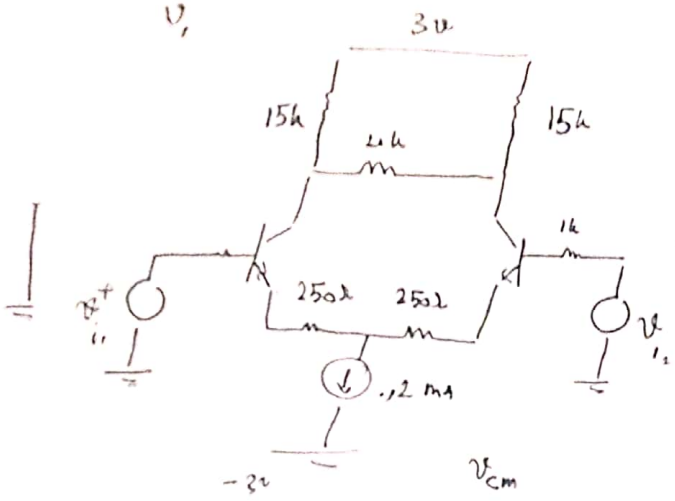
Q_4

$\rightarrow \frac{v^+}{0{,}88} + v_1 - 33 \geq 0{,}2v$

$\frac{v^-}{0{,}88} = 3{,}5 + v_1 \rightarrow (3{,}5 - v_1) \times 88 \leq 0{,}19$

$2{,}785 \leq v_1$

$v_{pp} = 0{,}19 \times 2 = 0{,}38$



$I_{C_1} = I_{C_2} = ,1mA$

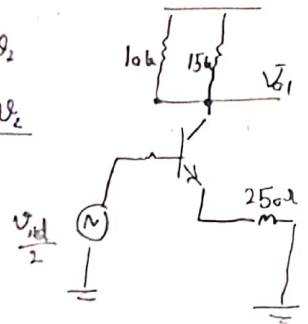
$r_{\pi_1} = r_{\pi_2} = 25k\Omega$

$r_{o_1} = r_{o_2} = 500k\Omega$

v_{cm}

$v_{id} = v_1 - v_2$

$v_{cm} = \frac{v_1 + v_2}{2}$



$10 \| 15 = 6k$

$CE = -\frac{6k}{,25k + \frac{25k+1k}{100}} = -11,76$

$v_{o1} = -11,76 \frac{v_{in}}{2}$ → $v_{o1} - v_{o2} = -11,76\, v_{in}$

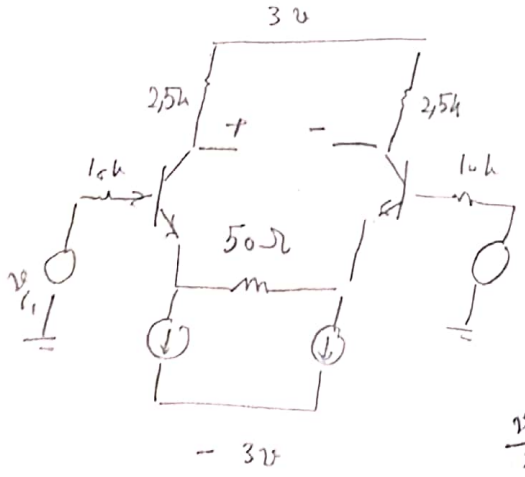
$v_{o2} = 11,76 \frac{v_{in}}{2}$ → $\frac{v_o}{v_{in}} = -11,76$

$R_{th} = 25k + 250\Omega \times 100 = 50k\Omega$

$v^- > \frac{,2 - 2,2}{1} = -2$

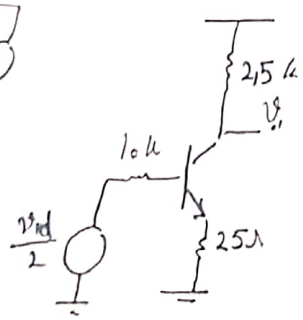
$3v - 6 \times ,1 =$

$v^+ < \frac{6 \times ,1}{16}$ → $v_{SV_{o1}} = 1,2v$ → $V_{P-P} = 2,4v$



$I_{C_1} = I_{C_2} = 1mA$ $\quad r_\pi = 2,5k\Omega$

$V_{CE} = 3 - 2,5 \times 1mA = ,5v - \left(-,7 - 10k \times \frac{1}{100} \right) = 1,3v$



$\frac{v_{o1}}{\frac{v_{id}}{2}} = -\frac{2,5 \times 10^3}{25 + \frac{2500 + 100\omega}{100}} = -16,67$

$v_{o1} - v_{o2} = -16,67 v_{id}$

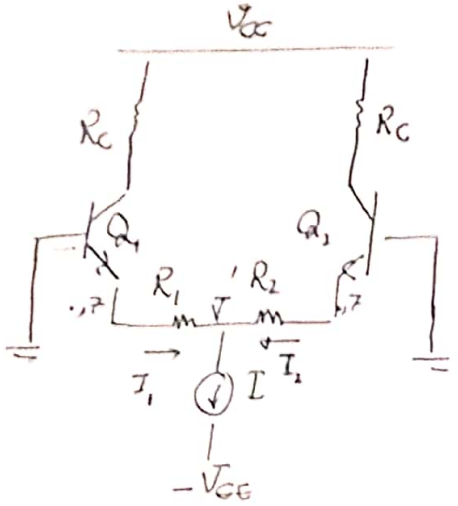
→ $A_v = -16,67$

$\frac{V^+}{2,5} = 1$ → $V^+ = 2,5$

$V^- + 1,5v > 2.$ → $V^- = -1,1$

$V_{P-P_{v_{o1}}} = V_{P-P_{v_{o2}}} = 1,1 \times 2 = 2,2$

$V_{P-P_{v_o}} = 4,4v$



I_S :

$$I_1 + I_2 = I$$

$$\begin{cases} I_{C_1} = kI_{S_0} e^{\frac{V_{BE}}{V_t}} \\ I_{C_2} = I_{S_0} e^{\frac{V_{BE}}{V_t}} \end{cases} \qquad \begin{cases} V_{BE_1} = 0 - (V' + R_1 I_1) \\ V_{BE_2} = 0 - (V' + R_2 I_2) \end{cases} \rightarrow V_{BE_2} - V_{BE_1} = R_1 I_1 - R_2 I_2$$

$$\rightarrow \frac{I_2}{I_1} = k e^{\frac{R_1 I_1 - R_2 I_2}{V_t}}$$

$$\rightarrow (I_1 = I_2) \rightarrow \ln \frac{1}{k} = \frac{(R_1 - R_2) I}{2 V_t}$$

$$\rightarrow R_1 - R_2 = \frac{2 V_t \ln\left(\frac{1}{k}\right)}{I} \rightarrow R_2 - R_1 = \frac{2 V_t}{I} \ln(k)$$