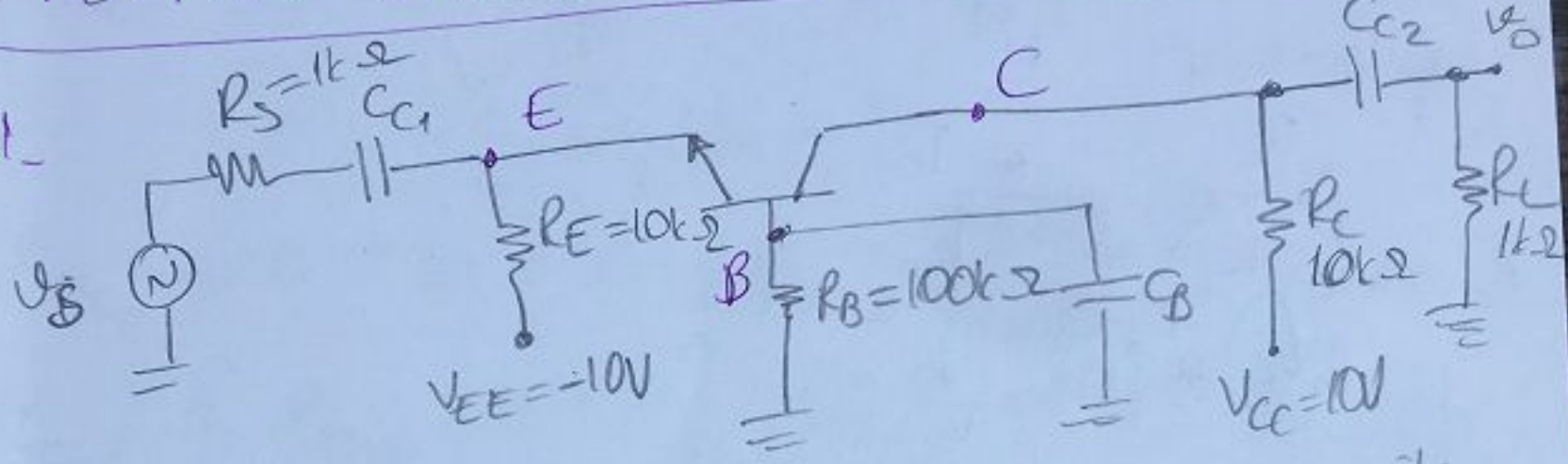
FREKANS ANALİZİ İLE İLGİLİ ÖRNEKLER ①

31_

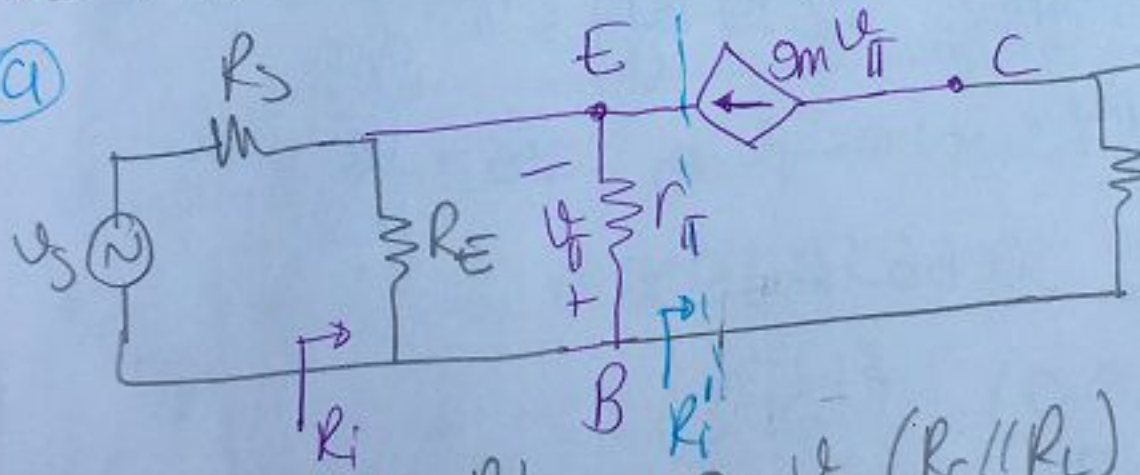


BJT parametreleri $\beta = 100$, $V_{BE} = 0,7V$ ve $V_A = \infty$ ile verildiğine ve $C_\pi = 24pF$, $C_\mu = 3pF$ olduğuna göre

a_ Orta frekans gerilim kazancı $A_{V_{Sof}} = \frac{v_o}{v_s}$ 'i bulunuz.

b_ Devrenin üst kesim frekansını bulunuz.

(a)



$$v_o = -g_m v_\pi \cdot R_L' = -g_m v_\pi (R_C // R_L)$$

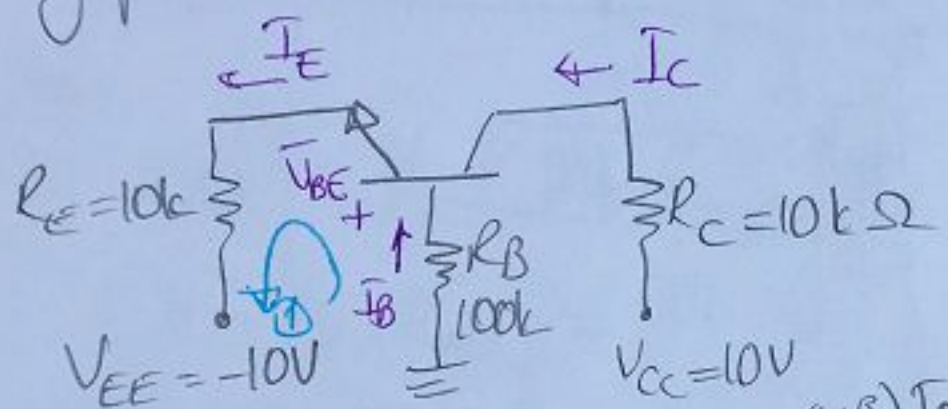
$$R_i' = \frac{v_E}{-g_m v_\pi} = \frac{-v_\pi}{-g_m v_\pi} = \frac{1}{g_m}$$

$$R_i = R_E // r_\pi // \frac{1}{g_m}$$

$$v_E = -v_\pi = \frac{R_i}{R_i + R_S} \cdot v_s$$

$$A_{V_{Sof}} = \frac{v_o}{v_s} = -g_m (R_C // R_L) \cdot \left(-\frac{R_i}{R_i + R_S}\right) = g_m R_C // R_L \cdot \frac{R_i}{R_i + R_S}$$

g_m ve r_π değerlerini bulmak için DC analiz ② yapılmalıdır:



① kolundan: $I_B R_B + V_{BE} + \widetilde{(1+\beta) I_B} R_E + V_{EE} = 0$

$$I_B = \frac{-V_{BE} - V_{EE}}{R_B + (1+\beta) R_E} = \frac{-0.7 + 10}{100k + 101 \cdot 10k} = 8.37\mu A$$

$$I_C = 0.837mA \;,\; I_E = 8.46mA$$

$$g_m = \frac{I_{CQ}}{V_{TH}} = \frac{0.837mA}{26mV} = 32.19 \frac{mA}{V} \;,\; r_\pi = \frac{\beta}{g_m} = 3.1k$$

$$r_o = \frac{V_A}{I_{CQ}} = \infty$$

$$R_i = R_E // r_\pi // \frac{1}{g_m} = 30.66\Omega$$

$10k \quad 3.1k \quad 31.06\Omega$

$$R_L' = R_C // R_L = 10k // 1k = 0.909k$$

$$A_{V_{SOF}} = \left(32.19 \cdot 10^{-3}\right) \left(0.909 \cdot 10^{3}\right) \cdot \frac{30,66}{1030.66} = 0.852$$

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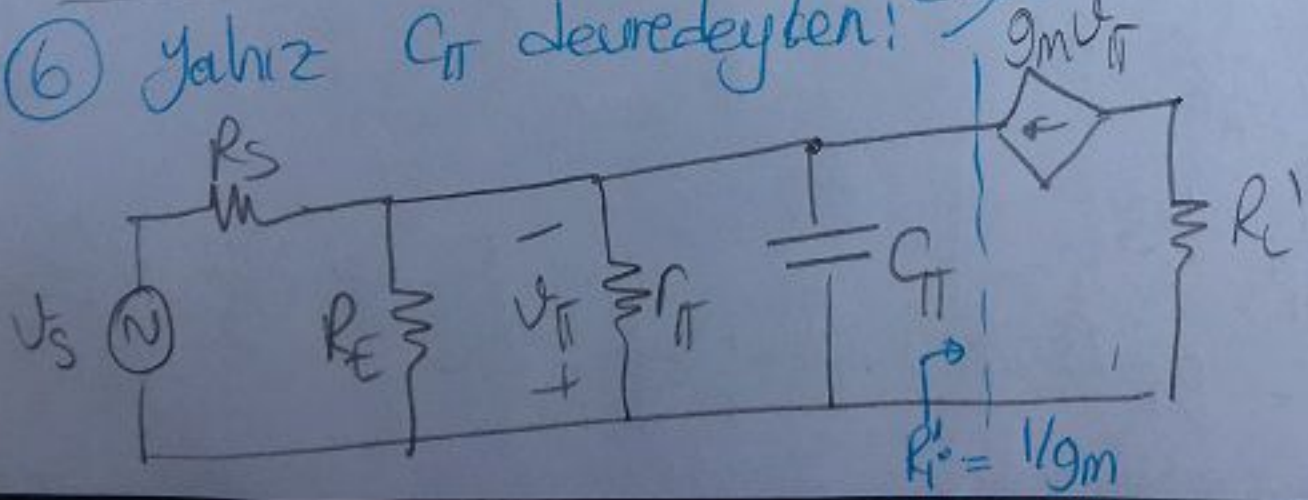
⑥ Yalnız C_π deyerdeyken: (Çıkış deyre)



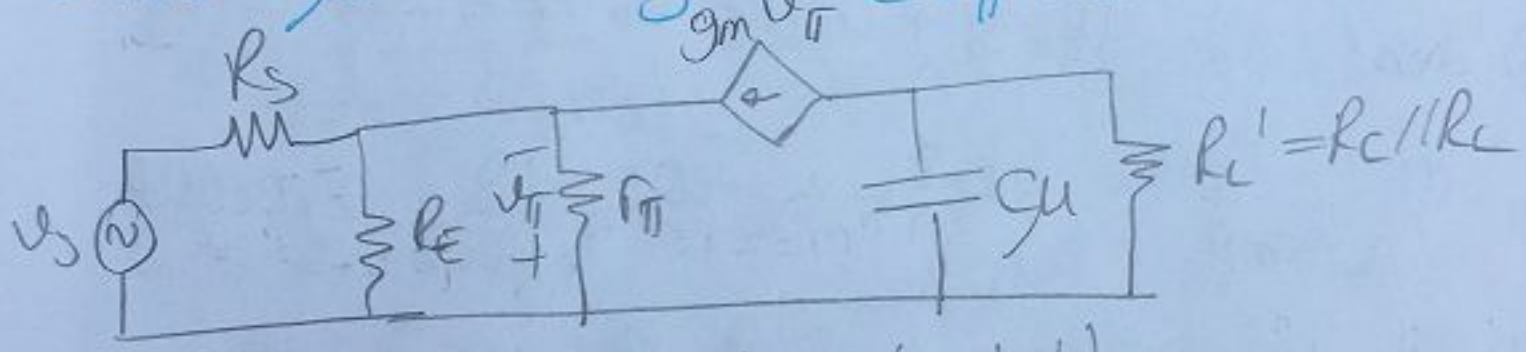
$$R_{esC_\pi} = R_S // R_E // r_\pi // \underbrace{\frac{1}{g_m}}_{\frac{r_\pi}{1+\beta} = \frac{3.1k}{101} =} = R_S // R_E // \frac{r_\pi}{1+\beta}$$

$$R_{esC_\pi} = 1k // 10k // 30.69\Omega = 29.69\Omega$$

$$\tau_{C_\pi} = C_\pi \cdot R_{esC_\pi} = (24.10^{-12}) \cdot (29.69) = 0.712ns$$

$$\omega_{C_\pi} = 1,403.10^9 rad/s \quad , f_{C_\pi} = 223MHz$$

Yalnız C_μ devredeyken (C_π açık devre)



$v_s = 0$ için $v_\pi = 0$, $g_m v_\pi = 0$ (açık d.)

$$R_{esC_\mu} = R_L' = 0.909k\Omega$$

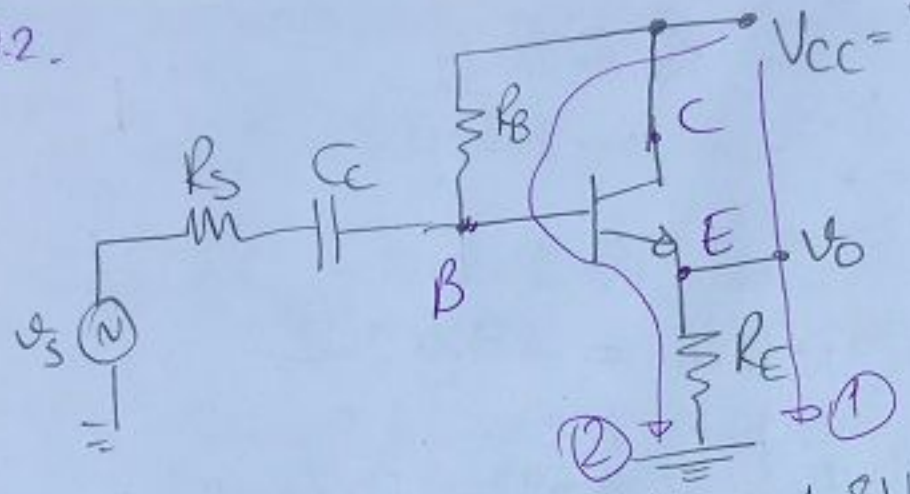
$$\tau_{C_\mu} = C_\mu \cdot R_{esC_\mu} = (3.10^{-12}) \cdot (0.909.10^3) = 2.727ns$$

$$\omega_{C_\mu} = 366.7 Mrad/s \quad , f_{C_\mu} = 58.3MHz$$

$$f_H = Min\{f_{C_\mu}, f_{C_\pi}\} = 58.3MHz$$

veya $$f_H = \frac{1}{2\pi(\tau_{C_\mu} + \tau_{C_\pi})} = 46.27MHz$$

S.2.



$R_S=100\Omega$

BJT parametreleri
($\beta=120$, $V_{BE}=0,7V$, $V_n'=\infty$)

a- $I_{EQ}=0.25mA$ ve $V_{CEQ}=1.8V$ olması için R_B ve R_E=?

b- $f_L=20Hz$ olması için C_C ne olmalıdır?

c- Orta frekans gerilim kazancını bulunuz.

a. ① 'den: $V_{CC}=V_{CEQ}+I_{EQ}R_E \Rightarrow R_E=\dfrac{V_{CC}-V_{CEQ}}{I_{EQ}}$

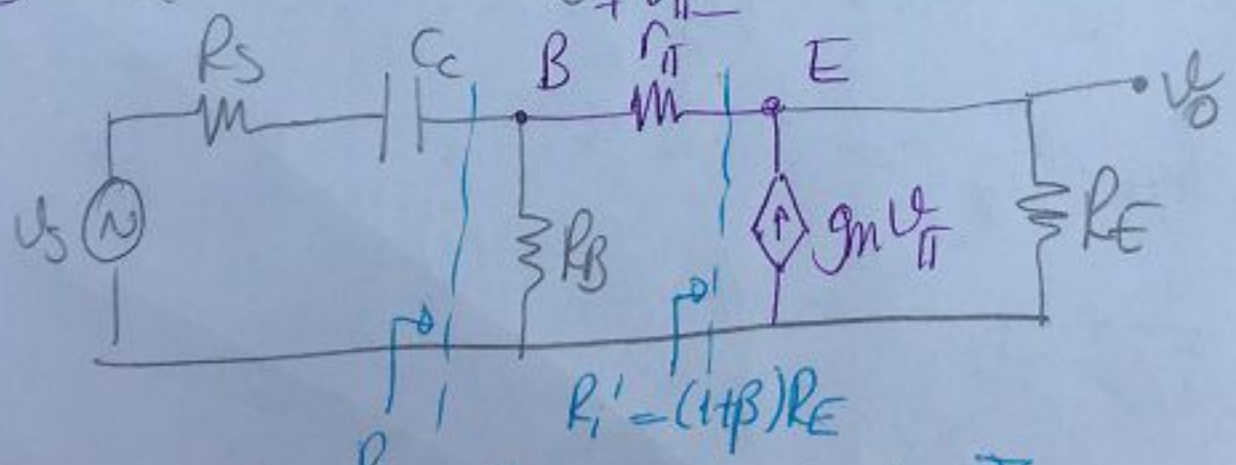
$R_E=\dfrac{(3.3-1.8)V}{0.25mA}=6k\Omega$, $I_{BQ}=\dfrac{I_{EQ}}{1+\beta}=2,066\mu A$

② 'den: $V_{CC}=I_BR_B+V_{BE}+I_ER_E$

3.3V 0.7V 1.5V

$R_B=\dfrac{V_{CC}-V_{BE}-I_ER_E}{I_B}=532.42k\Omega$

(b) Alçak Fr. Eşdeğer Devresi:



$R_i=R_B \,//\, [r_\pi+(1+\beta)R_E]$

C_C uçlarından görülen eşdeğer direnç:

$$R_{eq_C} = R_S + R_i = R_S + R_B \,//\, [r_\pi + (1+\beta) R_E]$$

$$I_{CQ} = \beta I_{BQ} = 0.2479\,mA \;,\; g_m = \frac{I_{CQ}}{V_{Th}} = 9.535\,\frac{mA}{V} \;,\; r_\pi = 12.59\,k\Omega$$

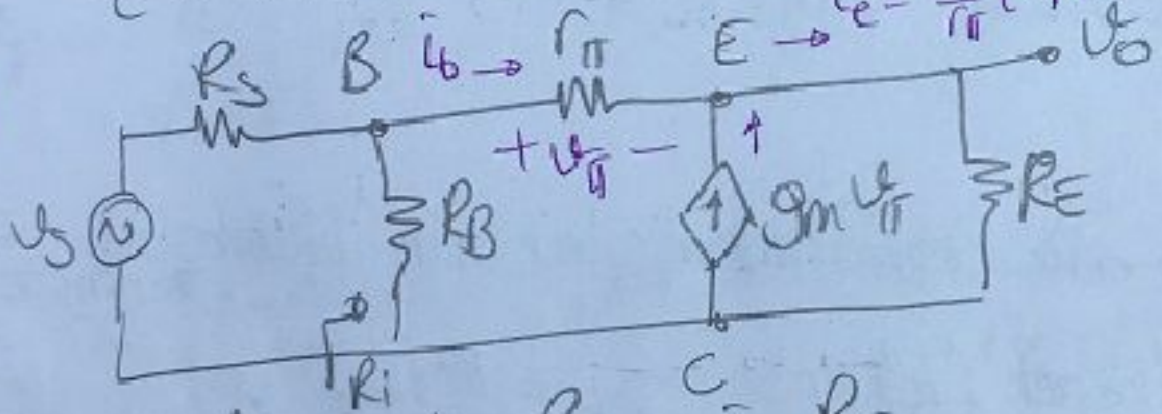
$$R_i = \underbrace{532.42}_{R_B} \,//\, \underbrace{[12.59k + (121)6k]}_{738.6k} = 309.25\,k\Omega$$

$$X_{C_C} = C_C \cdot (R_i + R_S) = \frac{1}{2\pi f_L} = \frac{1}{2\pi (20\,Hz)}$$

$$C_C = \frac{1}{2\pi f_L (R_i + R_S)} = \frac{1}{2\pi (20) \cdot (309.35\,k\Omega)}$$

$$C_C = 2.57 \cdot 10^{-8}\,F = 25.7\,nF$$

(c)



$$v_o = \frac{v_\pi}{r_\pi}(1+\beta) \cdot R_E = i_e \cdot R_E$$

$$v_B = v_\pi + v_o = \frac{v_\pi}{r_\pi}\left[r_\pi + (1+\beta) R_E\right]$$

$$v_B = \frac{R_i}{R_i + R_S} \cdot v_S$$

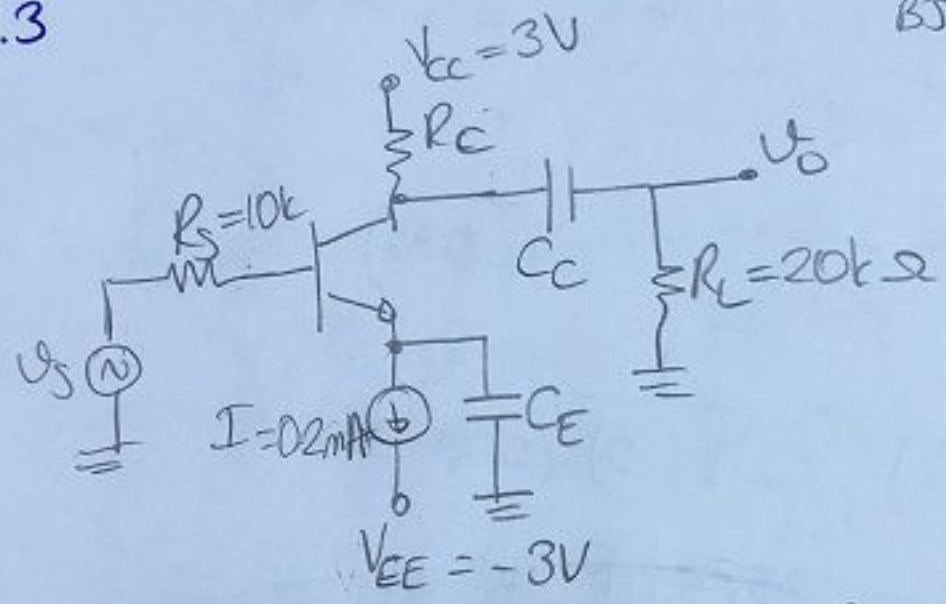
$$A_{V_{Sf}} = \frac{v_o}{v_S} = \frac{v_o}{v_\pi}\,\frac{v_\pi}{v_B}\,\frac{v_B}{v_S} = \left(\frac{R_E}{r_\pi}(1+\beta)\right)\left(\frac{r_\pi}{r_\pi + (1+\beta) R_E}\right)\left(\frac{R_i}{R_i + R_S}\right)$$

$R_i \gg R_S \Rightarrow \dfrac{R_i}{R_i+R_S} \cong 1$

$$A_{V_{Sof}} = \frac{(1+\beta)R_E}{r_\pi + (1+\beta)R_E} = \frac{(121)\,6k}{12.59+(121)6k} = 0.983$$

5.3

BJT Tr. parametreleri:
$\beta = 120, V_{BE} = 0.7V, V_A = \infty$



a- $V_{CEQ} = 2.2V$ olması için R_C ne olmalıdır?

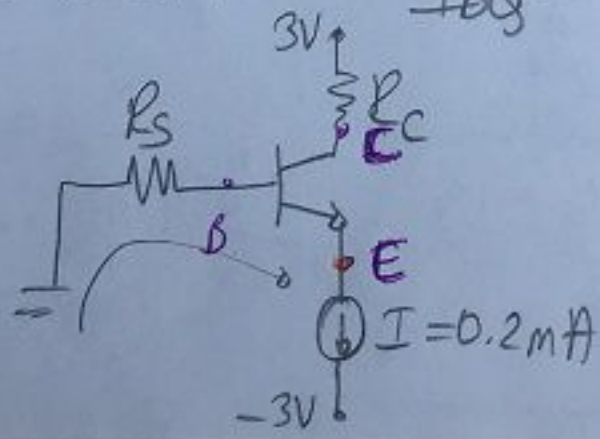
b- $A_{V_{Sof}} = ?$

c- C_C ve C_E 'ye ait köşe frekanslarının ifadesini veriniz.

d- C_E 'ye ait köşe frekansı $f_{C_E} = 10Hz$ ve C_C'ye ait köşe frekansı $f_{C_C} = 50Hz$ ise C_E ve C_C değerlerini bulunuz.

(a) $I = I_{EQ} = 0.2mA \Rightarrow I_{BQ} = 1.653\mu A,\ I_{CQ} = 0.198mA$

DC analiz devresi:



$V_E = -(I_B R_S + V_{BE})$

$V_E = -0.7165V$

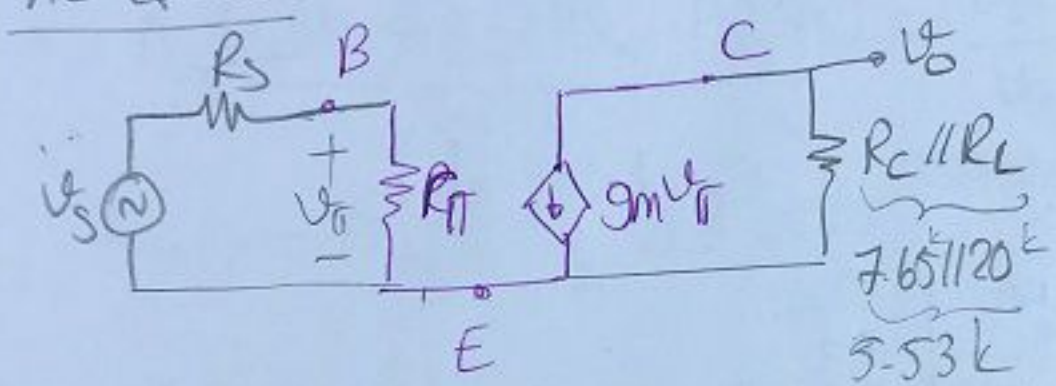
$V_C = V_E + V_{CEQ} = 1.483V$

$$R_C = \frac{V_{CC} - V_C}{I_{CQ}} = \frac{(3 - 1.483)V}{0.198mA} = 7.65k\Omega$$

(b) $$g_m = \frac{0.198mA}{0.026V} = 7.627mA/V$$

$$r_\pi = \frac{\beta}{g_m} = 15.73k\Omega \;,\; r_o = \frac{V_A}{I_{CQ}} = \infty$$

AC Eşd. Dev:



(DC akım kaynağı AC eşdeğer devrede açık devre alınacak, E ucu C_E nedeniyle orta frekanslarda topraktadır)

$$v_o = -g_m v_\pi . (R_C // R_L)$$

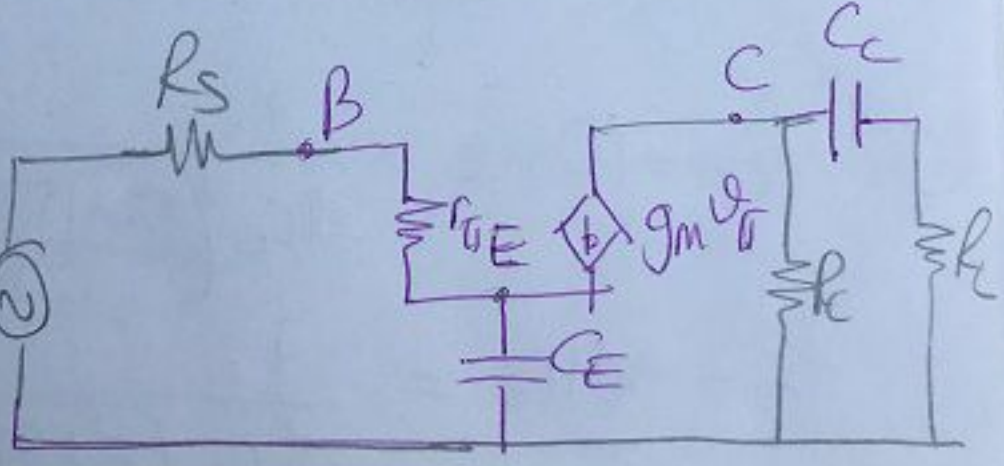
$$v_\pi = \frac{R_i}{R_i + R_S} . v_s \;,\; R_i = r_\pi$$

$$A_{V_{Sof}} = \frac{v_o}{v_s} = -g_m (R_C // R_L) . \frac{r_\pi}{r_\pi + R_S}$$

$$A_{V_{Sof}} = -(7,627.10^{-3}).(5,53.10^{3}) . \frac{15.73k}{25.73k}$$

$$A_{V_{Sof}} = -25,8$$

(c) ~~Alçak Fr.~~ Alçak Fr. Eşdeğer Devresi;



Yalnız C_C devredeyken (C_E kısa d)

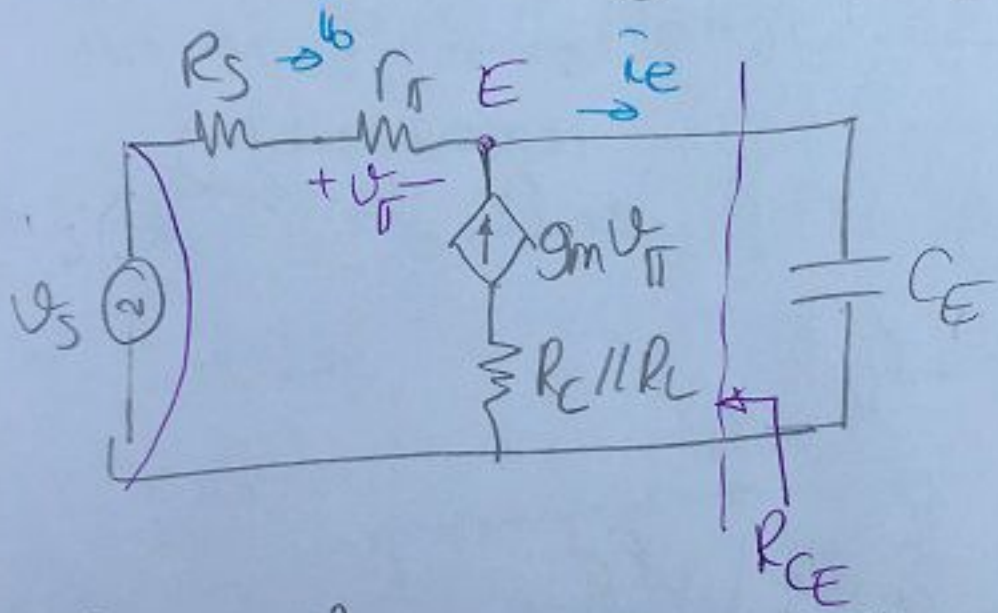
$v_s \to 0$ için $v_\pi = 0$, $g_m v_\pi = 0$ (açık d.)

C_C uçlarından görülen eşdeğer direnç R_{C_C}:

$$R_{C_C} = (R_C + R_L)$$

$$\tau_{C_C} = C_C (R_C + R_L) \quad , \quad f_{C_C} = \frac{1}{2\pi C_C (R_C + R_L)}$$

Yalnız C_E devredeyken (C_C kısa d.)



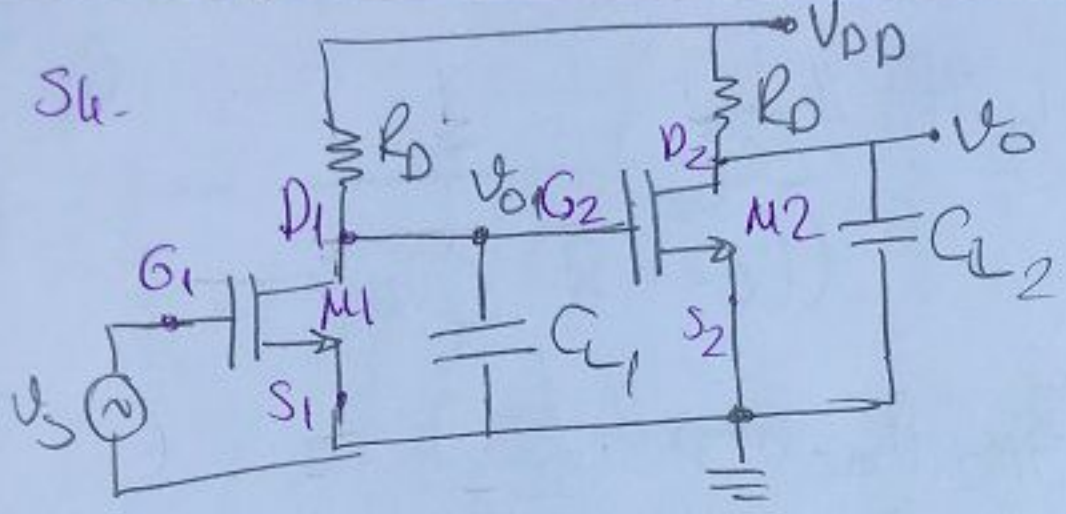
$$R_{CE} = \frac{v_E}{-i_e} = \frac{-(R_S + r_\pi) \cdot i_b}{-(1+\beta) i_b} = \frac{R_S + r_\pi}{(1+\beta)}$$

$$\tau_{C_E} = C_E \left(\frac{R_S + r_\pi}{1+\beta}\right) \quad , \quad \omega_{C_E} = \frac{1}{\tau_{C_E}} \quad , \quad f_{C_E} = \frac{1}{2\pi C_E \left(\frac{R_S + r_\pi}{1+\beta}\right)}$$

(d) $f_{C_E} = 10\,Hz = \dfrac{1}{2\pi C_E \left(\frac{10k + 15 \| 73k}{121}\right)} \to C_E = 74.8\,\mu F$

$f_{C_C} = 50\,Hz = \dfrac{1}{2\pi C_C (7.65k + 20k)} \to C_C = 0.115\,\mu F$

Sk-



Şekildeki devrede MOS parametreleri:

$K_{n_1} = K_{n_2} = 1.6\,mA/V^2$

$\lambda_1 = \lambda_2 = 0.02\,V^{-1}$

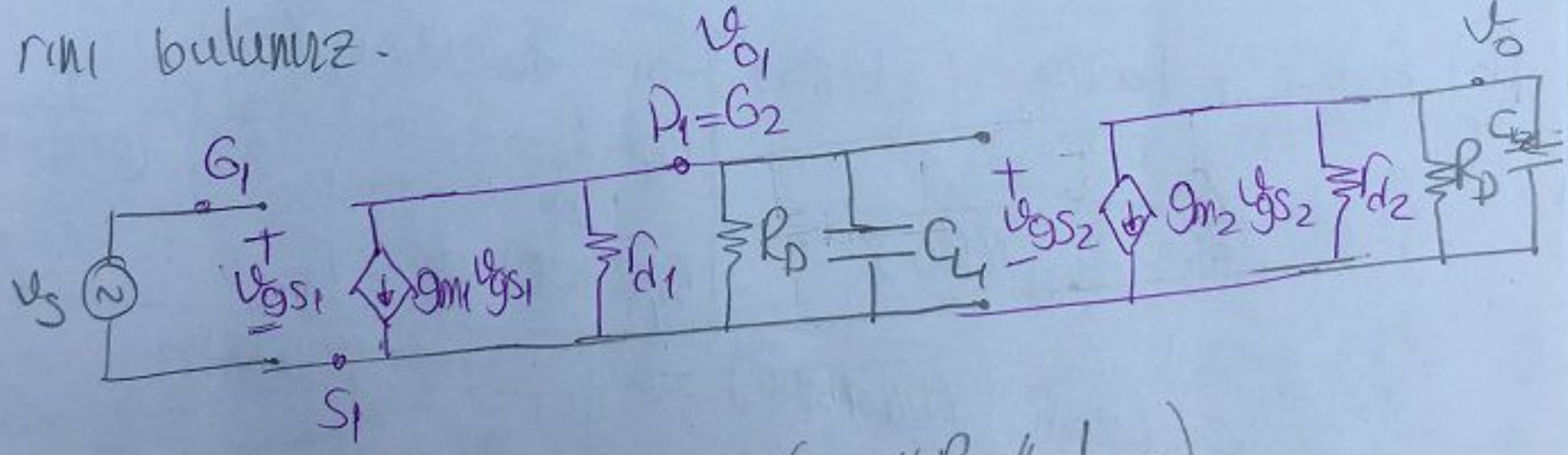
ve $I_{D1} = I_{D2} = 0.5mA$

$R_D = 5k\Omega$, $C_1 = 12pF = C_{L2}$

a- $A_{V_1}(s) = \dfrac{v_{o_1}(s)}{v_s(s)}$, $A_{V_2}(s) = \dfrac{v_o(s)}{v_{o_1}(s)}$ ve

$A_V(s) = A_{V_1}(s) \cdot A_{V_2}(s) = \dfrac{v_o(s)}{v_s(s)}$ ifadelerini bulunuz

b- $A_{V_1}(s)$, $A_{V_2}(s)$ ve $A_V(s)$ 'in alt kesim frekanslarını bulunuz.



(a) $v_{o_1} = v_{gs_2} = -g_{m_1} v_{gs_1} \cdot (r_{d_1} /\!/ R_D /\!/ \dfrac{1}{sC_1})$

$A_{V_1}(s) = \dfrac{v_{o_1}(s)}{v_s(s)} = -g_{m_1} (r_{d_1} /\!/ R_D /\!/ \dfrac{1}{sC_1})$

$A_1(s) = -g_{m_1} \dfrac{r_{d_1} /\!/ R_D}{1 + sC_1 \underbrace{(r_{d_1} /\!/ R_D)}_{\tau_L}}$

$$v_o(s) = -g_{m_2} v_{gs_2}(s) \left(r_{d_2} \| R_D \| \frac{1}{sC_{L_2}}\right)$$

$$v_{o_1}(s) = v_{gs_2}(s)$$

$$A_{v_2}(s) = \frac{v_o(s)}{v_{o_1}(s)} = -g_{m_2}\left(r_{d_2} \| R_D \| \frac{1}{sC_{L_2}}\right)$$

$$A_{v_2}(s) = -g_{m_2} \frac{r_{d_2} \| R_D}{1 + sC_{L_2}(r_{d_2} \| R_D)} \rightarrow \tau_2$$

$$A_v(s) = \frac{v_o(s)}{v_s(s)} = A_{v_1}(s) \cdot A_{v_2}(s) = g_{m_1} g_{m_2} \frac{r_{d_1} \| R_D}{1 + sC_{L_1}(r_{d_1} \| R_D)} \times \frac{r_{d_2} \| R_D}{1 + sC_{L_2}(r_{d_2} \| R_D)}$$

$$I_D = \frac{1}{2} k_n (V_{GS} - V_T)^2 (1 + \lambda V_{DS})$$

$$g_m = k_n (V_{GS} - V_T)(1 + \lambda V_{DS})$$

$I_{D_1} = I_{D_2}$, $k_{n_1} = k_{n_2}$

$$r_{d_1} = \frac{1}{g_{d_1}} = \left[\frac{\partial I_{D_1}}{\partial v_{DS}}\right]^{-1} \cong \frac{1}{\lambda I_D} = \frac{1}{(0.02)(0.5m)}$$

$r_{d_1} \cong 100k\Omega = r_{d_2}$

(6) $A_{v_1}(s)$ 'in kesim frekans'

$$f_{L_1} = \frac{1}{2\pi C_{L_1}(r_{d_1} \| R_D)}$$

$$f_{L_1} = \frac{1}{2\pi (12.10^{-12})(4.762.10^3)} \Rightarrow f_{L_1} = 2.785 MHz$$

$A_{v_2}(s)$ 'in alt kesim frekans'

$$f_{L_2} = \frac{1}{2\pi C_{L_2}(r_{d_2} \| R_D)} = 2.785 MHz.$$

$$A_{v_s}(s) = g_{m_1} \cdot g_{m_2} \frac{(r_d \| R_D)^2}{[1 + sC_L(r_d \| R_D)]^2}$$

$$\left|\frac{1}{(1+jw C_L (r_d \parallel R_D))}\right|^2 = \frac{1}{\sqrt{2}}$$ olan frekansı arıyoruz.

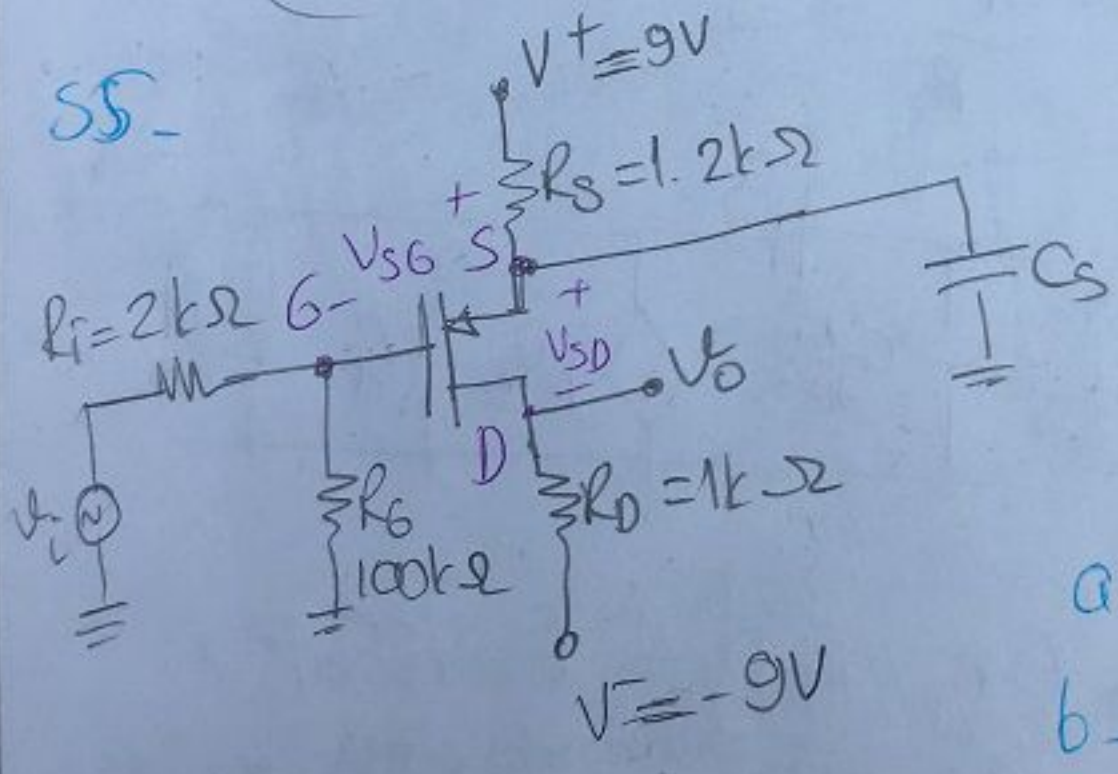
($w = w_L$'de kazanç max değerin $\frac{1}{\sqrt{2}}$'si olur)

$$\left(\frac{1}{\sqrt{1+[2\pi f_L C_L (r_d \parallel R_D)]^2}}\right)^2 = \frac{1}{\sqrt{2}} = 0.707$$

$$\frac{1}{1+\left(\frac{f_L}{2.785.10^6}\right)^2} = 0.707$$

$$\left(\frac{f_L}{2.785.10^6}\right)^2 = 0.4142 \Rightarrow f_L = 1.792\,MHz.$$

SS-



pMOS parametreleri

$K_p = 4mA/V^2$,

$V_{Tp} = -2V$, $\lambda = 0.01\frac{1}{V}$

$C_{gs} = 10pF$, $C_{gd} = 1pF$

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a- Eşdeğer Miller kapasitesini bulunuz.

b- Orta fr. gerilim kazancı $A_{vof} = \frac{v_o}{v_i}$ ve üst kesim frekansını bulunuz.

a- Öncelikle g_m, r_d için DC analiz yapılır:

$$I_D = \frac{K_p}{2}(V_{SG}+V_{T_p})^2 \underbrace{(1+\lambda V_{SD})}_{\approx 1} = \frac{9-V_{SG}}{R_S}$$

(DC analiz için AC kaynak $v_i \to 0$, G gerilimi $V_G = 0$ olur)

$$2(1,2)(V_{SG}-2)^2 = 9 - V_{SG}$$

$$2,4\,V_{SG}^2 - 8,6\,V_{SG} + 0.6 = 0 \to \sqrt{b^2-4ac} = 8.25$$

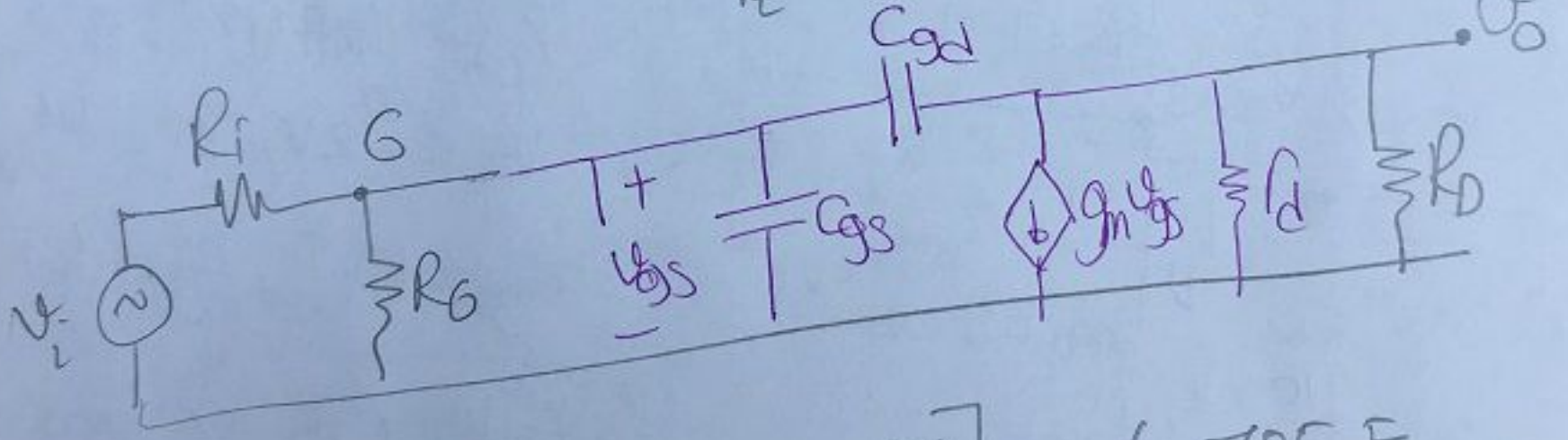
$$V_{SG_{1,2}} = \frac{8.6 \mp 8.25}{2.(2,4)} \to \begin{matrix} V_{SG_1} = 3.51\,V \to V_{SG} > |V_{T_p}| \text{ olmalı} \\ V_{SG_2} = 0.07\,V \quad \times \end{matrix}$$

$$I_D = 2.(3.51-2)^2 = 4,572\,mA$$

$$g_m \cong K_p.(V_{SG}+V_{T_p}) = 4.(3.51-2) = 6,049\,mA/V$$

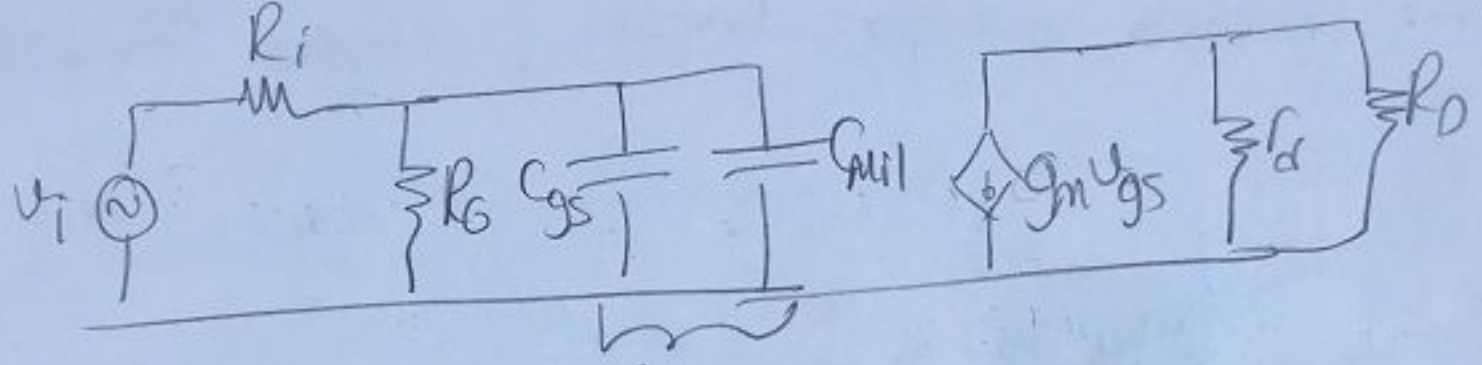
$$r_d = \frac{1+\lambda V_{SD}}{\lambda I_D} \cong \frac{1}{\lambda I_D} = \frac{1}{0.01.(4,572)} = 21.9k\Omega$$

$$C_{Mil} = C_{gd}\left[1 + g_m \underbrace{(r_d /\!/ R_D)}_{R_L'}\right]$$



$$C_{Mil} = 1pF\left[1 + g_m \underbrace{(r_d /\!/ R_D)}_{21.9k/\!/1.k}\right] = 6.785pF$$

$$C_{T_{op}} = C_{gs} + C_{Mil} = 16.785pF$$



C_{Top} uçlarından görülen eşdeğer direnç $R_i // R_G$

$$\tau_H = C_{Top} \cdot (R_i // R_G) = (16,785\,10^{-12}) \cdot (2k // 100k)$$

$$\tau_H = 3.29.10^{-8} s = 32.9\,ns$$

$$w_H = \frac{1}{\tau_H} = 3,039.10^7 rad/s, \quad f_H = \frac{1}{2\pi\tau_H} = \underline{4.84\,MHz}$$

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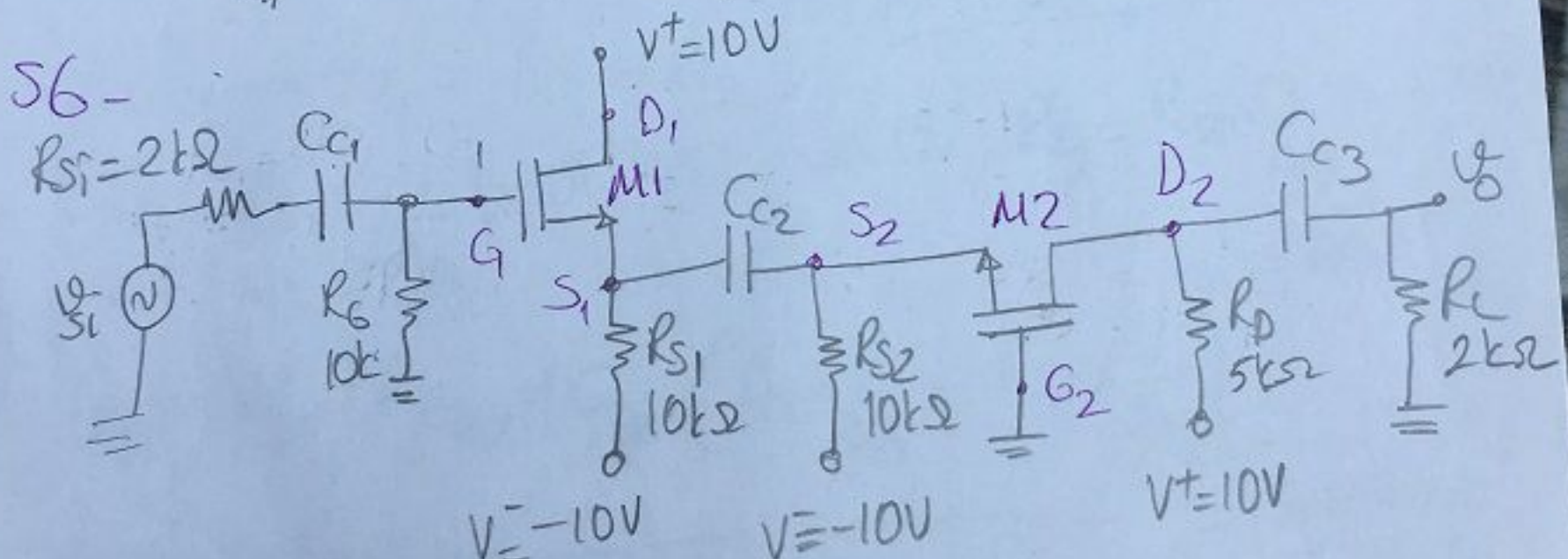


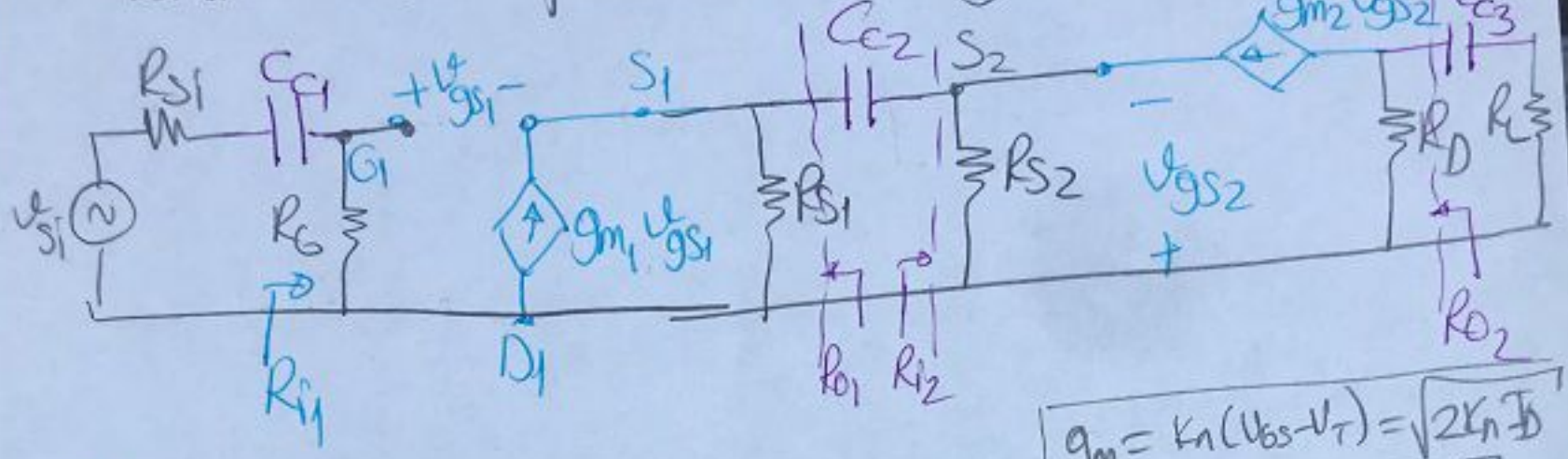
$$C_{C_1} = C_{C_2} = C_{C_3} = 4,7\,\mu F$$

M1 ve M2 parametreleri

$K_{n_1} = K_{n_2} = 80\,\mu A/V^2$, $V_{T_1} = V_{T_2} = 2V$, $\lambda_1 = \lambda_2 = 0$

$I_{D_1} = 1mA$, $I_{D_2} = 0.46mA$ olduğuna göre $f_L = ?$

Devrenin alçak frekans eşdeğer devresi:



$$g_m = K_n(V_{GS}-V_T) = \sqrt{2K_n I_D}$$
$$g_{m1} = \sqrt{2 \cdot 80\cdot10^{-6} \cdot 1\cdot10^{-3}}$$
$$g_{m1} = 0.4\ mA/V$$
$$g_{m2} = 0.271\ mA/V$$

C_{C1} için: $R_{eş1} = R_{Si} + R_{i1} = R_{Si} + R_G$

$$\tau_{C1} = C_{C1} \cdot R_{eş1} = C_{C1}(R_{Si}+R_G)$$

$$f_{C1} = \frac{1}{2\pi\tau_{C1}} = \frac{1}{2\pi C_{C1}(R_{Si}+R_G)} = \frac{1}{2\pi(4,7\cdot10^{-6})(12\cdot10^{3})}$$

$$\boxed{f_{C1} = 2.82\,Hz}$$

C_{C2} için: $R_{eş2} = R_{o1} + R_{i2}$

$R_{o1} = R_{S1} /\!/ \left(\frac{1}{g_{m1}}\right) = 10k /\!/ 2,5k = 2k\Omega$, $R_{i2} = R_{S2} /\!/ \frac{1}{g_{m2}}$ ($\frac{1}{g_{m2}} \approx 3.68k$)

$$\tau_{C2} = C_{C2} \cdot R_{eş2} = C_{C2}\left(R_{S1} /\!/ \frac{1}{g_{m1}} + R_{S2} /\!/ \frac{1}{g_{m2}}\right)$$

$$f_{C2} = \frac{1}{2\pi\tau_{C2}} = \frac{1}{2\pi C_{C2}\left(R_{S1} /\!/ \frac{1}{g_{m1}} + R_{S2} /\!/ \frac{1}{g_m}\right)} = \boxed{7.22\,Hz}$$

($C_{C2} = 4.7\mu F$, $\frac{1}{g_{m1}} \approx 2k$, $\frac{1}{g_m} \approx 2.69k$)

C_{C3} için: $R_{eş3} = R_{o2} + R_L$, $R_{o2} = R_D$

$$\tau_{C3} = C_{C3}\cdot(R_D + R_L),\quad f_{C3} = \frac{1}{2\pi C_{C3}(R_D+R_L)} = \boxed{4.837\,Hz}$$

$$f_L = \max\{f_{C1}, f_{C2}, f_{C3}\} = 7,22\,Hz$$