Prova scritta di Elettronica – Corso di Laurea in Ingegneria delle Telecomunicazioni

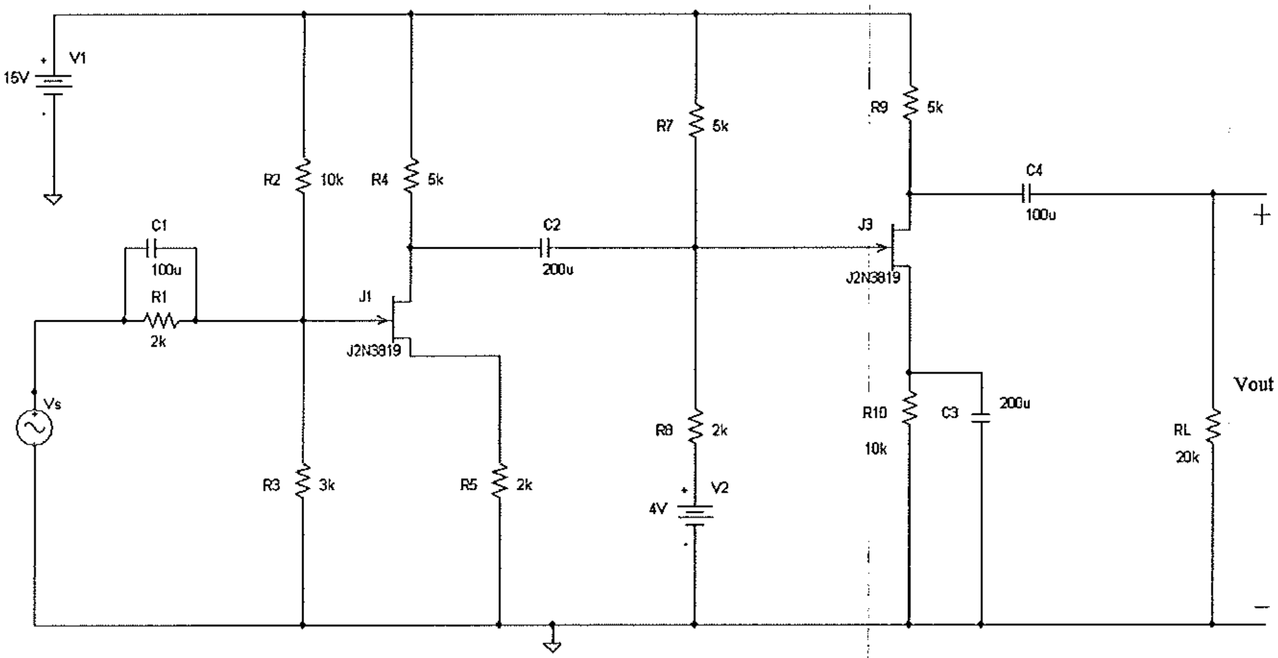
9 Settembre 2011

1. Si supponga di avere a disposizione un amplificatore operazionale con resistenza di ingresso infinita, resistenza di uscita R_{out}=100 Ω, amplificazione di tensione A_V=2000, un polo di modulo 1 Krad/s. Si scelgano componenti esterni e si progetti il circuito per realizzare un'amplificatore con resistenza di ingresso di 50 Ω, e resistenza di uscita maggiore di 1 KΩ. Si supponga il generatore d'ingresso ideale e il carico di 200 Ω. Calcolare il nuovo limite superiore di banda. È ammesso una tolleranza del 5% sulle specifiche.

2. Realizzare un filtro passabanda con frequenza centrale 8 KHz e banda passante 800 Hz. Disegnare il circuito, calcolare la funzione di trasferimento e dimensionare i componenti, giustificando il procedimento.

3. Dato l'amplificatore disegnato in figura calcolare:
   - Il punto di riposo dei 2 transistori e i parametri per piccolo segnale (punteggio 5/30);
   - L'amplificazione Vu/Vs a centrobanda (punteggio 4/30);
   - Il limite inferiore e superiore di banda (punteggio 8/30).

   I transistor sono 2N3819 con rd → ∞



1) $A_{v0} = 2000$

$s_p = 1\,\text{Krad/s}$

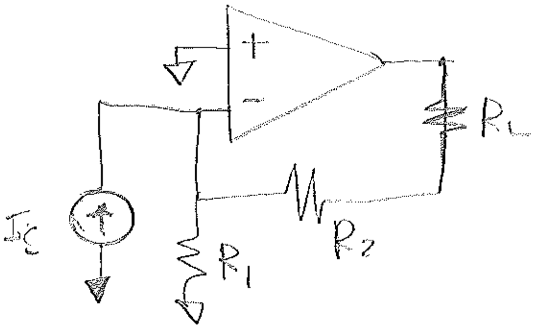
$R_{in} = \infty$

$R_{out} = 100\,\Omega$

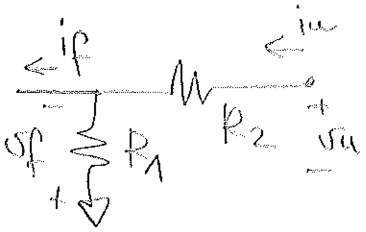
$R_L = 200\,\Omega$

$R_{IF} = 50\,\Omega$ ← inserzione di corrente

$R_{OF} > 1\,K\Omega$ ← prelievo di corrente



Rete per β



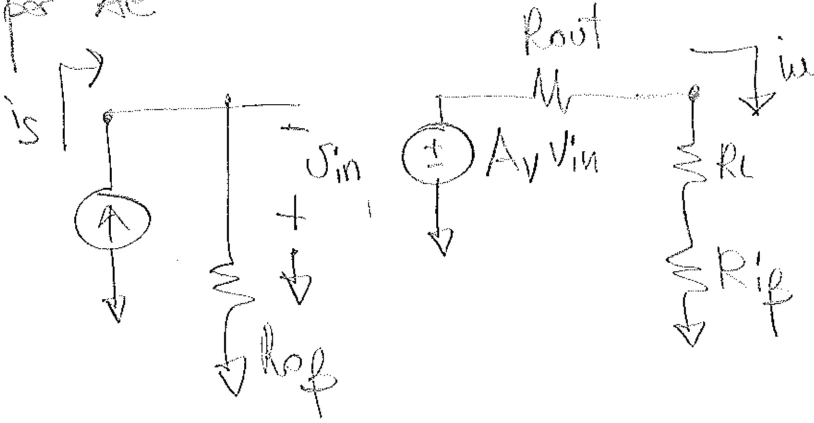
$i_f = \beta i_u + v_f / R_{of}$

$v_u = R_{i\beta} i_u + \cancel{K v_f}$

$$\beta = \left.\frac{i_f}{i_u}\right|_{v_f=0} = 1$$

$$R_{o\beta} = \left.\frac{v_f}{i_f}\right|_{i_u=0} = R_1 \qquad R_{i\beta} = \left.\frac{v_u}{i_u}\right|_{v_f=0} = R_2$$

Rete per A_e



$$A_e = \left.\frac{i_u}{i_s}\right| = \frac{-A_v R_{o\beta}}{R_{out} + R_L + R_{i\beta}}$$

$$\hat{R}_{IF} = \frac{R_{O\beta}}{(1-\beta A_e)} = 50\ \Omega$$

$$R_{OF} = (R_{i\beta} + R_{out})(1-\beta A_e|_{R_L=0}) > 1K\Omega$$

$R_{out} = 100\Omega$

← è sufficiente che $(1-\beta A_e)_{R_L=0} > 10$

nota che $(1-\beta A_e)_{R_L=0} > 1-\beta A_e$

$$1-\beta A_e = 1 + \frac{A_V R_1}{R_{out} + R_L + R_2}$$

possiamo porre $R_{O\beta} = R_1 = 500\Omega$ e $1-\beta A_e = 10$

$$\beta A_e = -9$$

$$\frac{A_V R_1}{R_{out} + R_L + R_2} = 9 \Rightarrow R_2 = \frac{A_V R_1}{9} - R_{out} - R_L =$$

$$= \frac{2000 \cdot 500}{9} - 100 - 200 =$$

$$R_2 = 110.81\ K\Omega$$

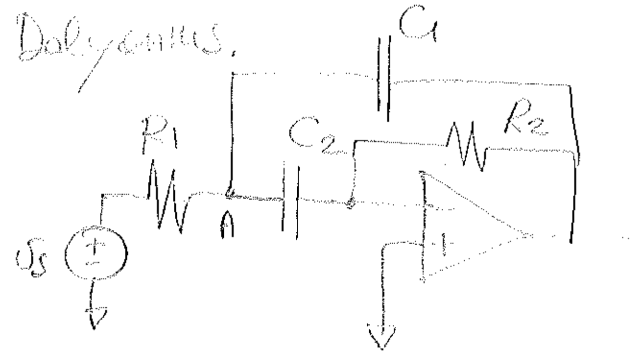
$$R_{OF} = (R_2 + R_{out})\left(1 + \frac{A_V R_1}{R_{out} + R_L}\right) = R_2 + R_{out} + A_V R_1 =$$

$$= 110.81 + 0{,}1 + 2000 \cdot 0{,}5 =$$

$$= 1{,}11\ K\Omega$$

$$f_H = \frac{|S_p|(1-\beta A_e)}{2\pi} = \frac{1000 \cdot 10}{6.28} = 1{,}59\ KHz$$

9) Realizziamo un filtro Biquad passabanda di Dolyanius.



Vogliamo
$f_0 = 8KHz$
$B = 800Hz$
$\hookrightarrow Q = 10 = f_0/B$

$$v_A\left[C_2 s + C_1 s + \frac{1}{R_1}\right] - \frac{v_S}{R_1} - C_1 s v_u = 0$$

$$v_A C_2 s + \frac{v_u}{R_2} = 0 \qquad v_A = \frac{-v_u}{R_2 C_2 s}$$

$$v_u\left[\frac{(C_1+C_2)R_1 s + 1}{R_2 C_2 s}\right] - v_S - R_1 C_1 s v_u = 0$$

$$v_u = \frac{v_S \quad R_2 C_2 s}{R_1 R_2 C_1 C_2 s^2 + R_1(C_1+C_2)s + 1}$$

$$R_1 R_2 C_1 C_2 = \frac{1}{\omega_0^2}$$

$$R_1(C_1+C_2) = \frac{1}{\omega_0 Q} \rightarrow Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{R_1(C_1+C_2)} =$$

$$Q = \sqrt{\frac{R_2}{R_1}} \cdot \left(\frac{\sqrt{C_1 C_2}}{C_1+C_2}\right)$$

$$\left(\frac{\sqrt{C_1 C_2}}{C_1+C_2}\right) = \frac{1}{2}$$

poniamo $C_1 = C_2 =$

$$\frac{R_2}{R_1} = 400$$

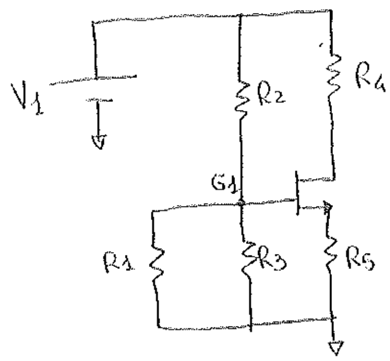
$$400 R_1^2 C_1^2 = \frac{1}{\omega_0^2} = \frac{1}{(2\pi)^2 8000^2} = 3{,}96 \cdot 10^{-10}$$

$R_2 = 40k\Omega$

scegliamo $R_1 = 100\,\Omega \rightarrow C_1 = \sqrt{\frac{3{,}96 \cdot 10^{-10}}{4000000}} = 10\,nF$

3) PUNTO DI RIPOSO

- JFET 1



$$V_{G1} = V_1 \cdot \frac{R_1 /\!/ R_3}{R_1 /\!/ R_3 + R_2} \cong 1.607\,V$$

$$V_{GS1} = V_{G1} - V_{S1}$$

$$V_{GS1} = V_{G1} - R_5 I_{DS1}$$

$$I_{DS1} = \frac{V_{G1} - V_{GS1}}{R_5}$$

$$\begin{cases} V_{GS}' = 0 \\ V_{GS}'' = -3V \end{cases} \Rightarrow \begin{cases} I_{DS}' = 0.81mA \\ I_{DS}'' = 2.3mA \end{cases}$$

$$V_{GS1} \cong -1.85\,V \qquad I_{DS1} \cong 1.73mA$$

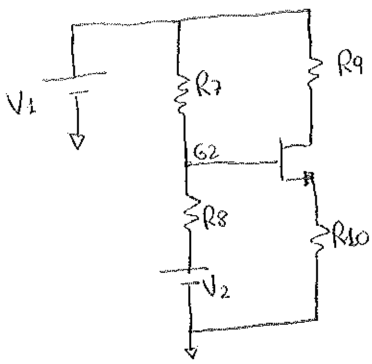
$$V_{DS1} = V_1 - (R_4 + R_5) I_{DS1} \cong 2.89\,V$$

VERIFICA JFET IN SATURAZIONE

$V_{GS} > V_{GSoff} = -3V$ OK!

$V_{DS} > V_{GS} - V_{GSoff} = -1.85 + 3 = 1.15\,V$ OK!

- JFET 2



Principio di sovrapposizione degli effetti

$$V_{G2} = V_{G2}' + V_{G2}''$$

$$V_{G2}' = \frac{R_8}{R_7 + R_8} \cdot V_1 \cong 4.286V$$

$$V_{G2}'' = \frac{R_7}{R_7 + R_8} \cdot V_2 \cong 2.857V$$

$$V_{G2} \cong 7.143V$$

$$V_{GS2} = V_{G2} - V_{S2}$$

$$V_{GS2} = V_{G2} - R_{10} \cdot I_{DS2}$$

$$I_{DS2} = \frac{V_{G2} - V_{GS2}}{R_{10}}$$

$$\begin{cases} V_{GS2}' = 0 \\ V_{GS2}'' = -3V \end{cases} \qquad \begin{cases} I_{DS2}' \cong 0.71\,mA \\ I_{DS2}'' \cong 1.01\,mA \end{cases}$$

$$V_{GS2} \cong -2.15V \qquad I_{DS2} \cong 0.93\,mA$$

$$V_{DS2} = V_1 - (R_9 + R_{10}) I_{DS2} \cong 1.05V$$

VERIFICA JFET IN SATURAZIONE

$V_{GS} > V_{GSoff} = -3V$ OK!

$V_{DS} > V_{GS} - V_{GSoff} = -2.15 + 3 = 0.85V$ OK!

PARAMETRI PICCOLO SEGNALE

- JFET 1

$g_{m1} \cong 2.9\,mS$ (curva in funzione di V_{GS})

$C_{iss1} \cong 2.6\,pF$

$C_{rss1} \cong 1.4\,pF$

$C_{GD1} = C_{rss1} \cong 1.4\,pF$

$C_{GS1} = C_{iss1} - C_{rss1} \cong 1.2\,pF$

- JFET 2

$g_{m2} \cong 2.1\,mS$ (curva in funzione di V_{GS})

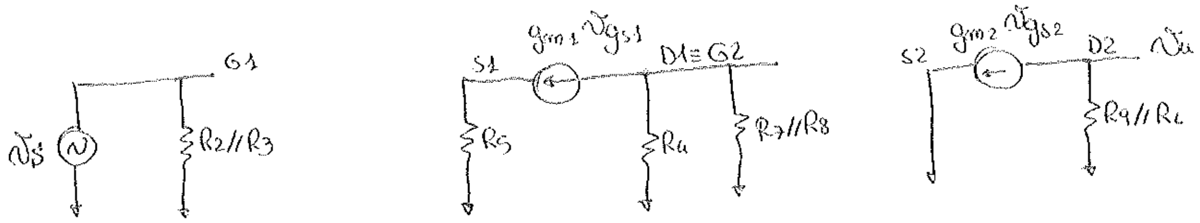
$C_{iss2} \cong 2.4\,pF$

$C_{rss2} \cong 1.2\,pF$

$C_{GD2} = C_{rss2} \cong 1.2\,pF$

$C_{GS2} = C_{iss2} - C_{rss2} \cong 1.2\,pF$

GUADAGNO A CENTRO BANDA



$$v_u = - R_9 /\!/ R_L \, g_{m2} \, v_{gs2}$$

$$v_{gs2} = v_{g2} - v_{s2} = v_{g2}$$

$$v_{g2} = - R_4 /\!/ R_7 /\!/ R_8 \, g_{m1} \, v_{gs1}$$

$$v_{gs1} = v_{g1} - v_{s1} = v_{g1} - g_{m1} v_{gs1} \cdot R_S$$

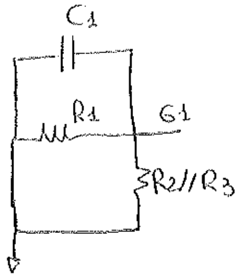
$$v_{gs1} = \frac{v_s}{1 + g_{m1} R_S}$$

$$v_{gs2} = - R_4 /\!/ R_7 /\!/ R_8 \cdot g_{m1} \frac{v_s}{1 + g_{m1} R_S}$$

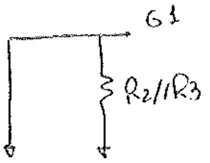
$$\frac{v_u}{v_s} = R_9 /\!/ R_L \cdot g_{m2} \cdot R_4 /\!/ R_7 /\!/ R_8 \cdot g_{m1} \cdot \frac{1}{1 + g_{m1} R_S}$$

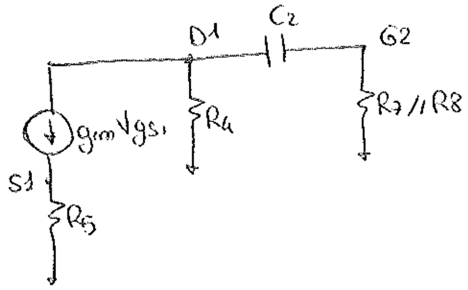
$$= 5 /\!/ 20 \cdot 2.1 \cdot 5 /\!/ 5 /\!/ 2 \cdot \frac{2.9}{1 + 2.9 \times 2} \cong 4$$

LIMITE INFERIORE DI BANDA

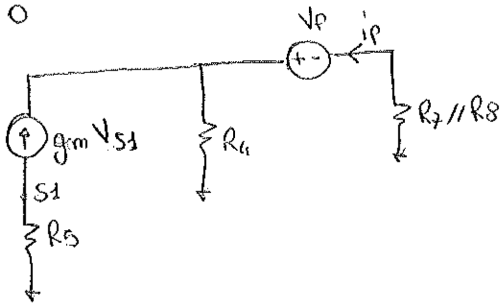


$R_{VC1} = R_1 // R_2 // R_3 \cong 1.07 K\Omega$





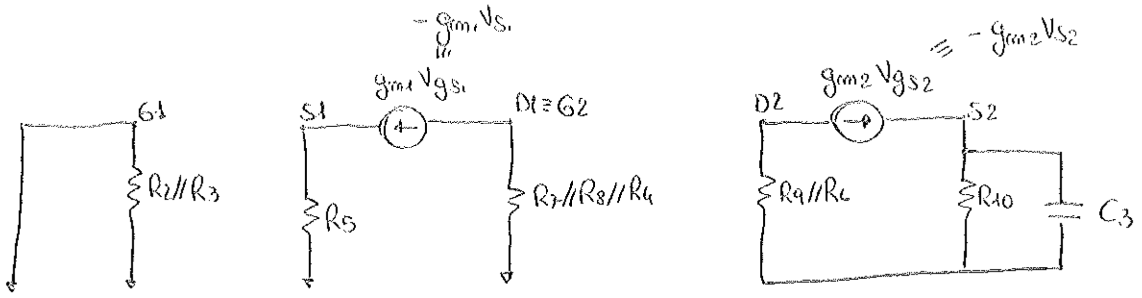
$V_{g1} = 0$



$V_p = R_4 \left(i_p + g_m V_{s1} \right) + R_7 // R_8 \cdot i_p$

$V_{s1} = - g_m R_5 V_{s1} \Rightarrow V_{s1} = 0$

$R_{VC2} = \frac{V_p}{i_p} = R_4 + R_7 // R_8 \cong 6.43 K\Omega$

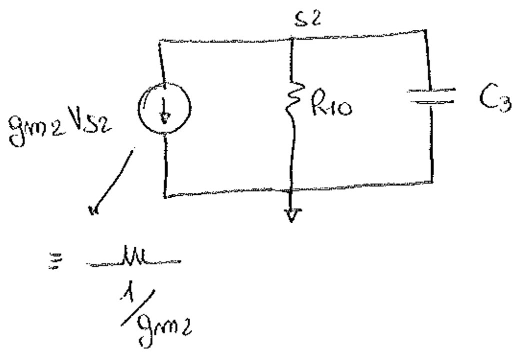


$V_{g1} = 0$

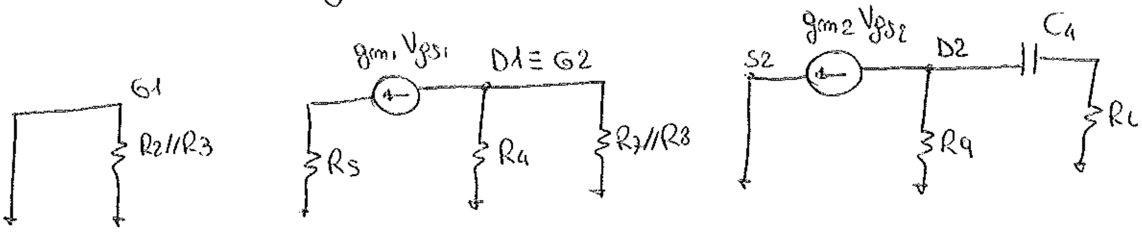
$V_{S1} = 0$ (vedi pag. prec.)

$V_{g2} = 0$

$V_{gs2} = -V_{S2}$



$$R_{VC3} = R_{10} // \frac{1}{g_{m2}} \cong 0.454\ k\Omega$$



$V_{g1} = 0$

$V_{S1} = 0$

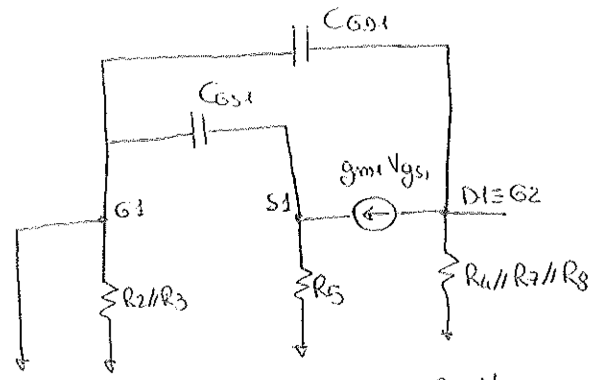
$V_{g2} = 0$

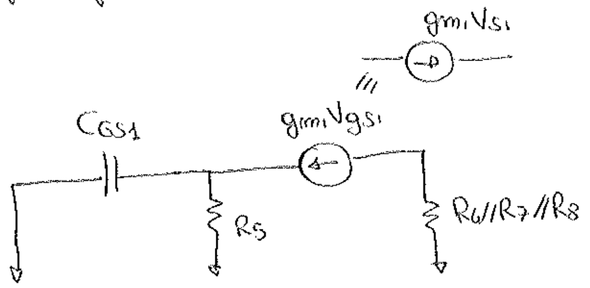
$V_{S2} = 0$

$$R_{VC4} = R_9 + R_L \cong 25\ k\Omega$$

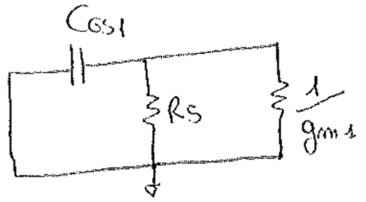
$$f_L = \frac{1}{2\pi}\left[\frac{1}{R_{VC1}\cdot C_1} + \frac{1}{R_{VC2}\cdot C_2} + \frac{1}{R_{VC3}\cdot C_3} + \frac{1}{R_{VC4}\cdot C_4}\right] \cong 3.43\ Hz$$

LIMITE SUPERIORE DI BANDA

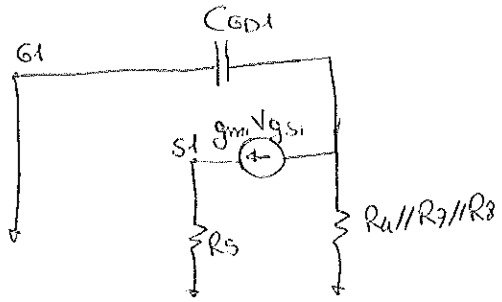




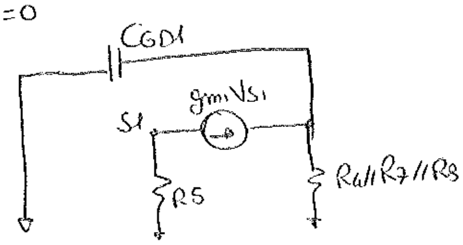
$V_{g1}=0$



$$R_{V_{CGS1}} = R_5 // \frac{1}{g_{m1}} \cong 0{,}294\,K\Omega$$

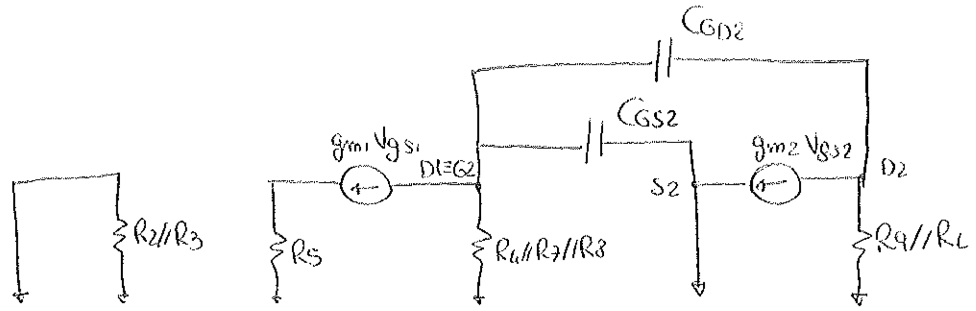


$V_{g1}=0$



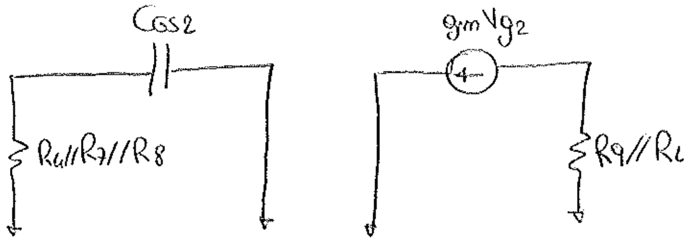
$V_{s1} = -R_5 g_{m1} V_{s1}$ $\qquad V_{s1}=0$

$$R_{V_{CGD1}} = R_4 // R_7 // R_8 \cong 1{,}7\,K\Omega$$

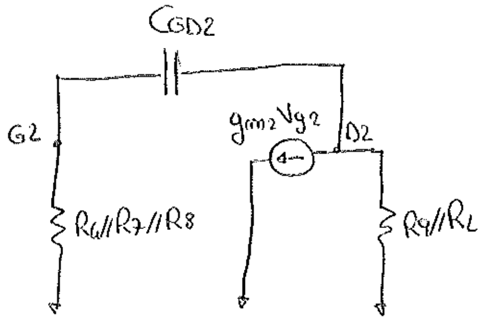


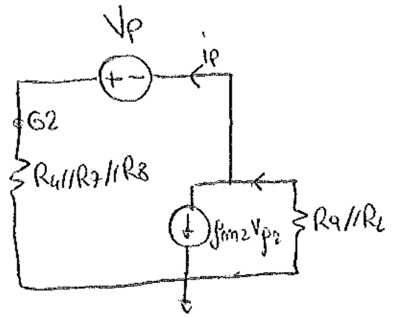
$V_{g1} = 0$

$V_{S1} = 0$



$$R_{V_{CGS2}} = R_4 // R_7 // R_8 \cong 1.7\ K\Omega$$





$$V_P = V_{g2} + R_9 // R_L \ (i_P + g_{m2} V_{g2})$$

$$V_{g2} = R_4 // R_7 // R_8 \cdot i_P$$

$$R_{V_{CGD2}} = \frac{V_P}{i_P} = R_4 // R_7 // R_8 + R_9 // R_L \left(1 + g_{m2} R_4 // R_7 // R_8\right) \cong 14.\bar{4}\ K\Omega$$

$$f_H = \frac{1}{2\pi\left[C_{GS1} \cdot R_{VC_{GS1}} + C_{GD1} \cdot R_{VC_{GD1}} + C_{GS2} \cdot R_{VC_{GS2}} + C_{GD2} \cdot R_{VC_{GD2}}\right]} \simeq 7.74\,MHz$$