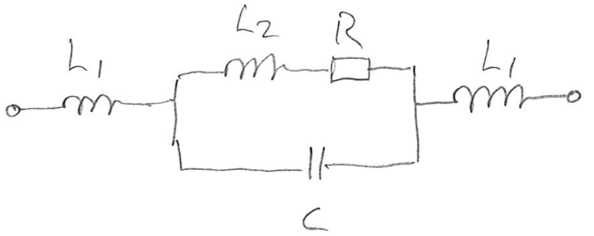
1 a)

Slew rate = maximala ändringshastigheten på op-amp utgången dvs $\left.\frac{du_{ut}}{dt}\right|_{max}$

b)



L_1: Induktans i anslut. trådar

L_2: -"- i motståndselement

C: Kapacitans i motståndselement

R: Ohmska förluster

Vid låga frekv $Z \approx R = 10k\Omega$

Vid högre frekvenser $Z \simeq \frac{1}{sC} = 3{,}74\Omega$ ~ typ 400 MHz

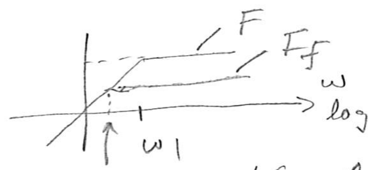
c) Switchade slutsteg ⇒ klass D

Slutransistor antingen leder ($v_{DS} = 0$) eller är avbrott ($i_D \simeq 0$)

dvs $P_T \simeq 0$ ⇒ verkningsgrad $\eta = 85-90\%$

d) $F(j\omega) = \frac{A_0 j\omega/\omega_1}{1 + j\omega/\omega_1}$; $F_f = \frac{F}{1+\beta F}$ där β är ett reellt tal vid resistivt nät

$$F_f = \frac{j\omega A_0/\omega_1}{1 + j\frac{\omega}{\omega_1} \cdot (1+\beta A_0)}$$



$\underline{\underline{\omega_f = \omega_1 / (1+\beta A_0)}}$

e) $T_j - T_a = P_T \cdot \Theta_{ja} \Rightarrow T_{a_{max}} = T_{j_{max}} - P_T \cdot \Theta_{ja}$

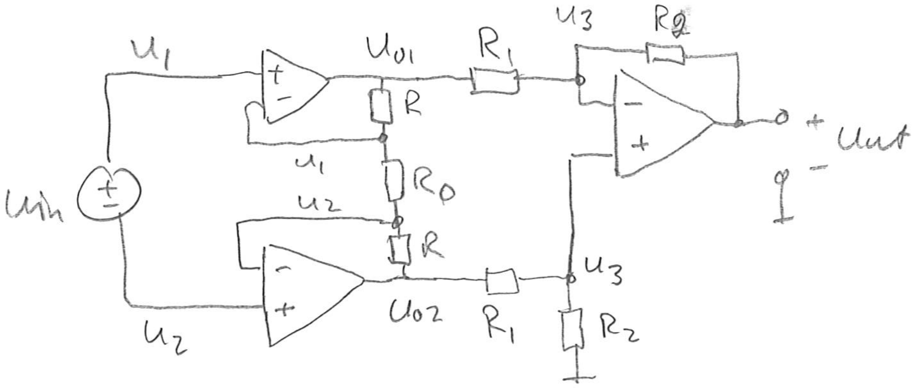
$T_{a_{max}} = 150 - 1 \cdot 62.5 = 87.5°C$

f) $P_{R_L max}(AC) = \left.\frac{\hat{i} \cdot \hat{u}}{2}\right|_{max} \Rightarrow \hat{i}_{max} = I_C,\ \hat{u}_{max} = E/2 \Rightarrow \underline{\underline{P_{R_L max}}} = \frac{I_C \cdot E}{2 \cdot 2} = \frac{50m \cdot 12}{4} = \underline{\underline{0{,}15\ W}}$

$$\eta_{max} = \frac{P_{R_L max}(AC)}{P_{Batt}} \cdot 100\% = \left(\frac{I_C \cdot E}{4} / I_C \cdot E\right) \cdot 100\% = 25\%$$

$P_{Batt} = E \cdot i_{C_{medel}} = E \cdot I_C$

② Bestäm U_{ut}/U_{in}



Neg. återkoppling $F=\infty$ } $\varepsilon = 0$; $R_i = \infty \Rightarrow i_{op} = 0$; $U_{in} = U_1 - U_2$

$$\frac{U_{01}-U_1}{R} + \frac{U_2-U_1}{R_0} = 0 \Rightarrow U_{01} = \frac{R}{R_0}\cdot U_{in} + U_1$$

$$\frac{U_{02}-U_2}{R} + \frac{U_1-U_2}{R_0} = 0 \Rightarrow U_{02} = \frac{-R}{R_0}\cdot U_{in} + U_2$$

$$U_{01} - U_{02} = \frac{2\cdot R}{R_0}\cdot U_{in} + U_{in} \quad (1)$$

$$\frac{U_{01}-U_3}{R_1} + \frac{U_{ut}-U_3}{R_2} = 0$$

$$U_3 = U_{02}\cdot\frac{R_2}{R_1+R_2}$$

$$U_{01} = \frac{R_1}{R_2}\cdot U_3 - U_{ut}\cdot\frac{R_1}{R_2} + U_3 \Rightarrow$$

$$U_{01} = \underbrace{\left(1+\frac{R_1}{R_2}\right)\cdot\frac{R_2}{R_1+R_2}}_{=1}\cdot U_{02} - U_{ut}\cdot\frac{R_1}{R_2} \quad (2)$$

(1) + (2)

$$U_{01} - U_{02} = U_{in}\left(1+\frac{2R}{R_0}\right) = -U_{ut}\cdot\frac{R_1}{R_2}$$

$$\therefore \quad \frac{U_{ut}}{U_{in}} = -\frac{R_2}{R_1}\left(1+\frac{2R}{R_0}\right)$$

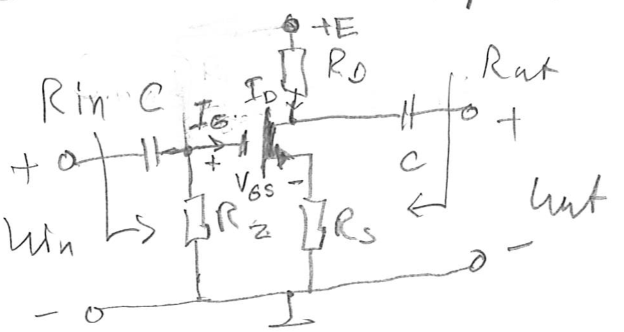
Dim ok?

③ Beräkna u_{ut}/u_{in}, R_{in} och R_{ut}

$V_t = 1\,V$; $k = 10\,mA/V^2$

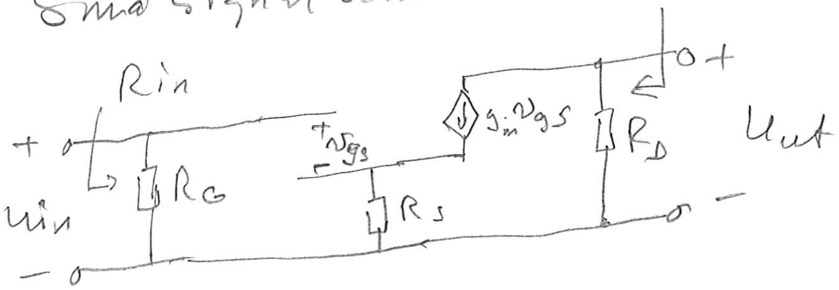
$R_D = 1\,k\Omega$; $R_S = 200\,\Omega$

$R_G = 500\,k\Omega$, $C = \infty$



$R_G = R_1 // R_2$

Små signal schema:



$u_{in} = v_{gs} + g_m \cdot v_{gs} \cdot R_S$

$u_{ut} = -g_m \cdot v_{gs} \cdot R_D$

$$\frac{u_{ut}}{u_{in}} = \frac{-g_m \cdot R_D}{1 + g_m \cdot R_S} = \frac{-6{,}2m \cdot 1k}{1 + 6{,}2m \cdot 200} \simeq 2{,}8 \text{ ggr}$$

$R_{in} = R_G = 500\,k\Omega$

$R_{ut}\big|_{u_{in}=0} = R_D = 1\,k\Omega$ då $v_{gs} = 0$

g_m?

$I_D = \frac{k}{2}(V_{GS} - V_t)^2$

Då $I_G = 0$ blir

$I_D = -V_{GS}/R_S$

$V_{GS}^2 - 2V_{GS}V_t + V_t^2 = -\frac{V_{GS}}{R_S} \cdot \frac{2}{k}$

$V_{GS}^2 + \left(\frac{2}{R_S k} - 2V_t\right) V_{GS} + V_t^2 = 0$

$\frac{2}{200 \cdot 0{,}01} + 2 = 3$

$V_{GS}^2 + 3V_{GS} + 1 = 0$

$V_{GS_{1,2}} = -\frac{3}{2} \pm \sqrt{\frac{9}{4} - \frac{4}{4}} = \frac{-3 \pm \sqrt{5}}{2}$

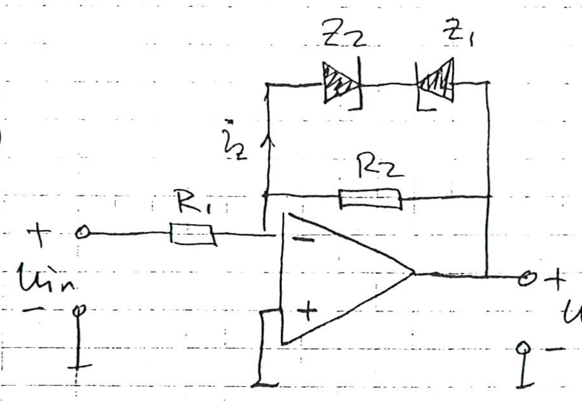
$V_{GS_{1,2}} = -0{,}38\,V$ $(-2{,}8)$

$I_D = \frac{-V_{GS}}{R_S} = \frac{0{,}38}{200} = 1{,}9\,mA$

$g_m = \sqrt{2k \cdot I_D} =$

$= \sqrt{2 \cdot 10m \cdot 1{,}9m} \approx 6{,}2\,m\frac{A}{V}$

(4)

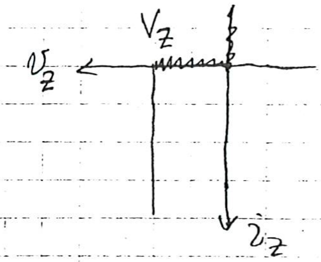


$V_{Z_1} = 5,1V$

$V_{Z_2} = 7,3V$

$R_1 = 1k\Omega$

$R_2 = 2k\Omega$



$F = \infty$

Neg. återkoppling } $\varepsilon = 0$

Zenerdioderna begränsar utsignalen uut:

∴ $-V_{Z_1} \leq Uut \leq V_{Z_2}$ (dynamiskt område)

I det dynamiska området spärrar båda zenerdioderna

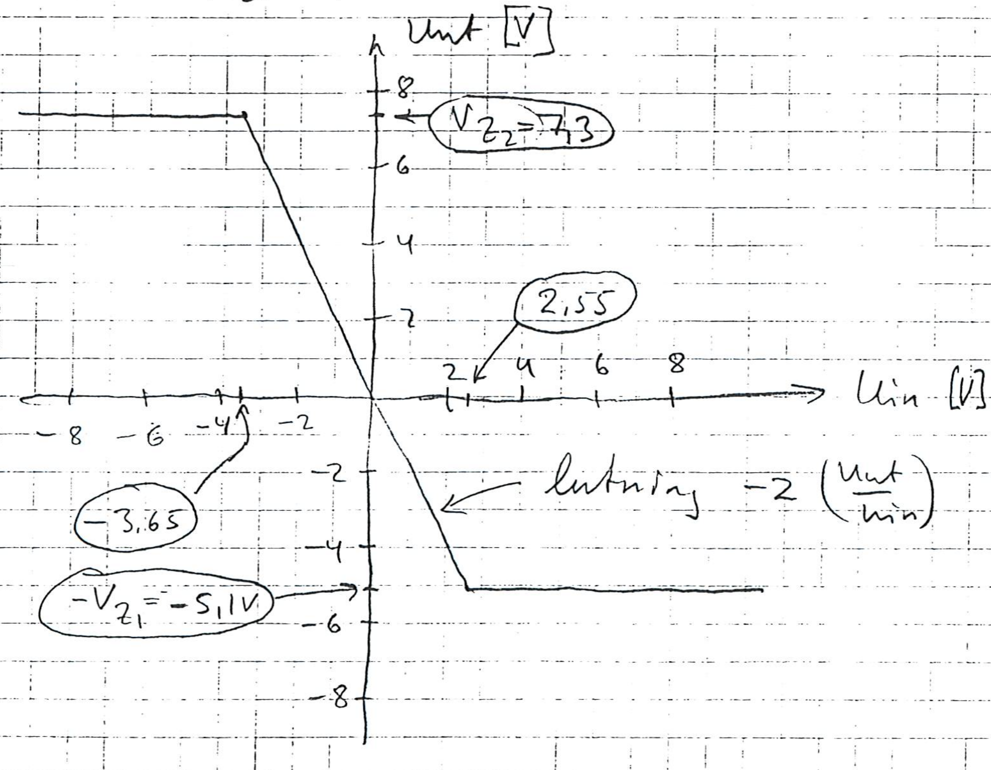
∴ $\frac{Uut}{Uin} = -\frac{R_2}{R_1} = -2$ ggr

Gränsfall (1): $Uut = V_{Z_2}$; $i_Z = 0$

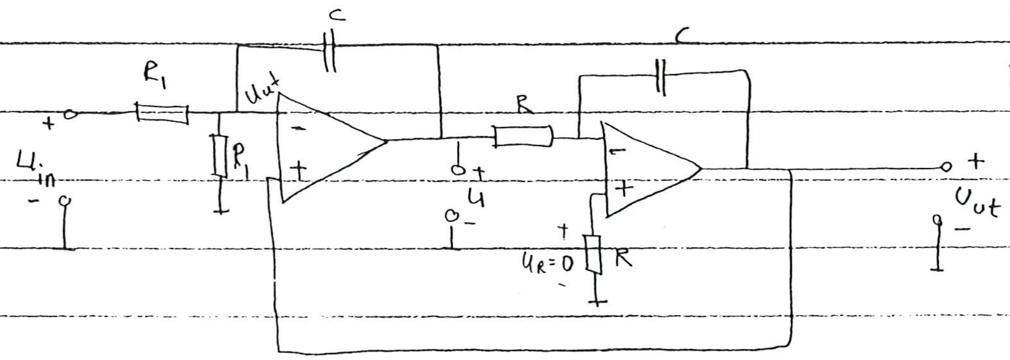
$Uin = -\frac{R_1}{R_2} \cdot Uut = -\frac{R_1}{R_2} \cdot V_{Z_2} = -3,65$ Volt

Gränsfall (2): $Uut = -V_{Z_1}$; $i_Z = 0$

$Uin = +\frac{R_1}{R_2} \cdot V_{Z_1} = 2.55$ Volt



(5)



Ideala Op-först, Neg. ÅK $\Rightarrow \varepsilon = 0$

$$\begin{cases} \dfrac{U_{in} - U_{ut}}{R_1} - \dfrac{U_{ut}}{R_1} + \dfrac{U - U_{ut}}{1/sC} = 0 & \Rightarrow U_{in} = 2U_{ut} + U_{ut} sR_1C - U sR_1C \\ \dfrac{U}{R} + \dfrac{U_{ut}}{1/sC} = 0 & \Rightarrow U = -U_{ut} sRC \end{cases}$$

$$U_{in} = U_{ut}\left[2 + sR_1C + s^2RR_1C^2\right]$$

$$\frac{U_{ut}}{U_{in}} = \frac{1/RR_1C^2}{s^2 + s\frac{1}{RC} + \frac{2}{RR_1C^2}}$$

Poler

$$s_{1,2} = -\frac{1}{2RC} \pm \sqrt{\underbrace{\frac{1}{4R^2C^2} - \frac{2}{RR_1C^2}}_{=0}}$$

ty kritisk dämpning

$$\frac{1}{4R^2C^2} = \frac{2}{RR_1C^2} \Rightarrow \frac{1}{4R} = \frac{2}{R_1} \qquad \boxed{R_1 = 8R}$$

$$\frac{U_{ut}}{U_{in}} = \frac{1/RR_1C^2}{(s+\omega_0)^2} \quad \text{där } \omega_0 = \frac{1}{2RC}$$

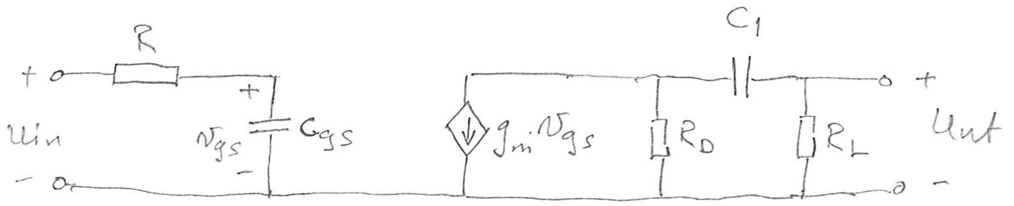
Kaskadkoppling: $\omega_{ötot} = \omega_0\sqrt{2^{1/4} - 1} \approx \frac{1}{2RC} \cdot 0{,}435 \approx \frac{0{,}217}{RC}$ rad/s

Bandbredd $= f_{ötot} \approx \frac{\omega_{ötot}}{2\pi} = 0{,}035/RC$ Hz

$$F_{max} = \left.\frac{U_{ut}}{U_{in}}\right|_{s=0} = \frac{1}{8R^2C^2} \cdot \frac{4R^2C^2}{1} = \frac{1}{2}$$

$$F_{max\,tot} = F_{max}^2 = \frac{1}{4} \text{ ggr} \Rightarrow -12\text{ dB}$$

(6)



$R = 100\ \Omega$

$R_D = 4k\ \Omega$

$R_L = 10k\ \Omega$

$C_1 = 2\mu F$

$k = 80\ mA/V^2$

$C_{gs} = 1nF$

$I_D = 10mA$

$\Delta t = 0{,}5ms$

$$g_m = \sqrt{2 \cdot k \cdot I_D} = \sqrt{2 \cdot 80m \cdot 10m} = 40m\ \frac{A}{V}$$

$$v_{gs} = u_{in} \frac{1}{1 + sRC_{gs}}$$

$$u_{ut} = -g_m \cdot v_{gs} \cdot \frac{R_D \cdot (R_L + \frac{1}{sC_1})}{R_D + R_L + \frac{1}{sC_1}} \cdot \frac{R_L}{R_L + \frac{1}{sC_1}}$$

$$\frac{u_{ut}}{u_{in}} = \frac{-g_m}{1 + sRC_{gs}} \cdot \frac{R_D \cdot \cancel{(1 + sR_LC_1)}}{1 + sC_1(R_D + R_L)} \cdot \frac{sR_LC_1}{\cancel{1 + sR_LC_1}}$$

$$\omega_2 = \frac{1}{RC_{gs}} = 10M\ \frac{rad}{sek}\ ; \quad \omega_1 = \frac{1}{C_1(R_D + R_L)} \simeq 35{,}7\ \frac{rad}{sek}$$

$$\left.\frac{u_{ut}}{u_{in}}\right|_{max} = \frac{g_m \cdot R_D \cdot \cancel{s} \cdot R_L \cdot \cancel{C_1}}{\cancel{s}\cancel{C_1}(R_D + R_L)} = \frac{40m \cdot 4k \cdot 10k}{4k + 10k} = \frac{1600}{14} = 114\ ggr$$

Maxförstärkning: $\left.\frac{u_{ut}}{u_{in}}\right|_{max} \simeq 114\ ggr \rightleftharpoons 41dB$

Stigtid: $t_r \simeq 2.2/\omega_ö \approx 2.2/\omega_2 \simeq 220\ nF$

Pulsfall: $P_{rel} = \Delta t \cdot \omega_1 \cdot 100\% = 0{,}5m \cdot 35{,}7 \cdot 100 \simeq 1{,}8\%$