Lösningar elektronik jan 2009

(1.)

a. Varaktor, varicap (kapacitansdiod)

b. Elektrolytkondensator

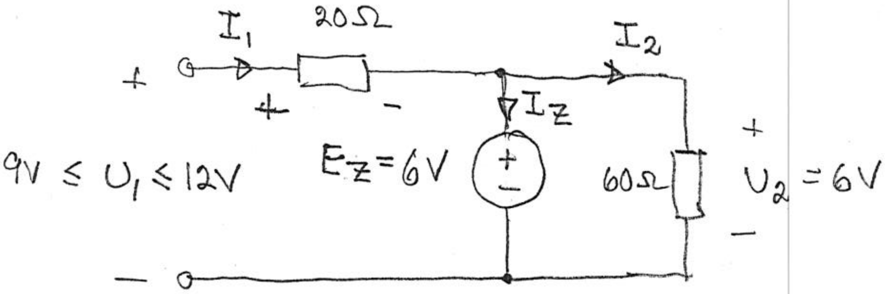
c. Drossel

d. $T_j - T_a = P_F \cdot R_{Thja}$. $R_{Thja} = R_{Thjc} + R_{Thcs} + R_{Thsa} =$

$= 1°C/W + 0 + 2°C/W = 3°C/W \Rightarrow$

$$P_{Fmax} = \frac{T_{jmax} - T_a}{R_{Thja}} = \frac{175°C - 40°C}{3°C/W} = \underline{\underline{45W}}$$

e. Schema då zenerdioden leder



$P_Z = E_Z \cdot I_Z$; $I_Z = I_1 - I_2$; $I_2 = \frac{6V}{60\Omega} = 100mA \Rightarrow$

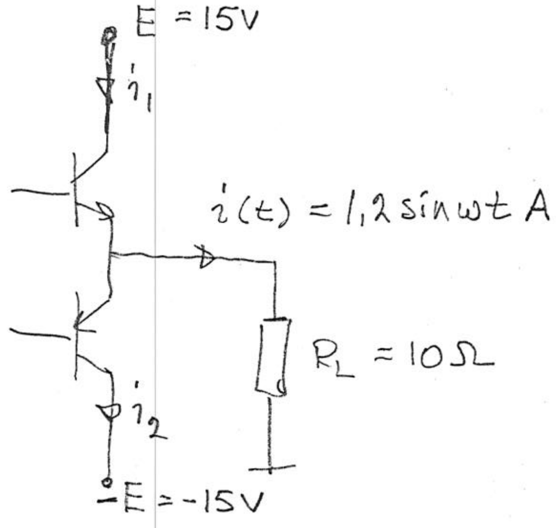
$I_Z = I_1 - 100mA$; $I_1 = \frac{U_1 - 6V}{20\Omega}$

$P_{Zmax} = E_Z \cdot I_{Zmax} = 6V \cdot I_{Zmax}$; $I_{Zmax} = I_{1max} - 100mA$;

$I_{1max} = \frac{U_{1max} - 6V}{20\Omega} = \frac{12V - 6V}{20\Omega} = 300mA \Rightarrow$

$P_{Zmax} = 6V \cdot (300mA - 100mA) = \underline{\underline{1{,}2W}}$

F. P_T = Effektutveckling i en transistor



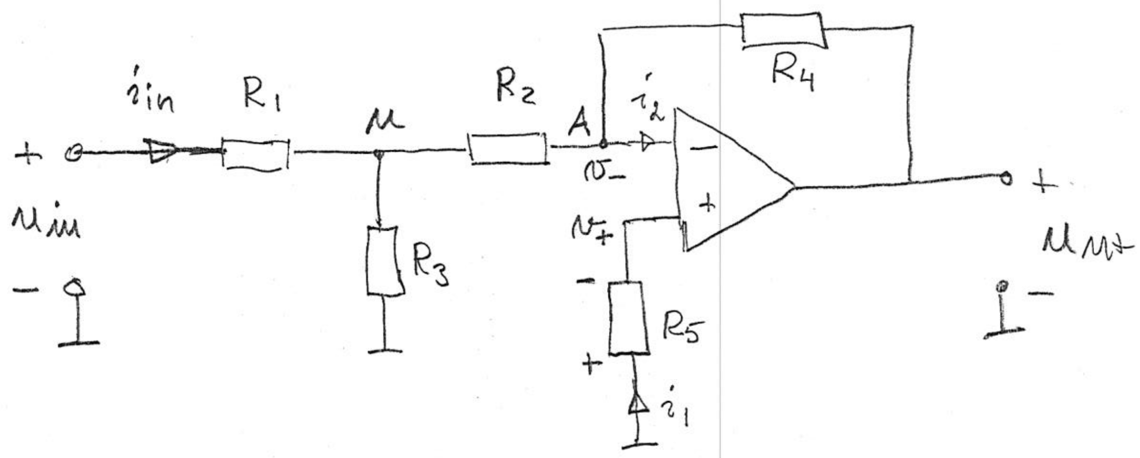
- $P_{in} = 2 \cdot E \cdot \overline{i_1}$
- $P_{ut} = R_L \cdot \frac{\hat{i}^2}{2}$
- $\overline{i_1} = \frac{\hat{i}_1}{\pi} = \frac{\hat{i}}{\pi} = \frac{1{,}2A}{\pi}$

$$\Rightarrow P_{in} = 2 \cdot 15V \cdot \frac{1{,}2A}{\pi} = 11{,}46W$$

$$P_{ut} = 10\Omega \cdot \frac{(1{,}2A)^2}{2} = 7{,}2W$$

$$P_{in} = P_{ut} + 2P_T \Rightarrow P_T = \frac{P_{in} - P_{ut}}{2} = \frac{11{,}46W - 7{,}2W}{2} = \underline{\underline{2{,}13W}}$$

2.



Ideal motkopplad OP $\Rightarrow$ $i_1 = i_2 = 0$; $v_+ = v_-$

$$\Rightarrow v_+ = 0 - R_5 \cdot i_1 = 0.$$

Nodanalys för att bestämma u_{ut}:

$\underline{u:}$ $$\frac{u - u_{in}}{R_1} + \frac{u}{R_3} + \frac{u - v_A}{R_2} = 0 \quad ; \; v_A = v_- = v_+ = 0 \Rightarrow$$

$$u \cdot \left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_2} \right) = \frac{1}{R_1} \cdot u_{in} \Rightarrow$$

$$u \left(1 + \frac{R_1}{R_3} + \frac{R_1}{R_2} \right) = u_{in} \Rightarrow u = \frac{1}{1 + \frac{R_1}{R_3} + \frac{R_1}{R_2}} \cdot u_{in} \quad (1)$$

$\underline{A:}$ $$\frac{v_A - u}{R_2} + \frac{v_A - u_{ut}}{R_4} = 0 \quad ; \; v_A = 0 \Rightarrow$$

$$u_{ut} = -\frac{R_4}{R_2} \cdot u \quad (2) \quad \text{(Inverterande Förstärkare)}$$

$$(1),(2) \Rightarrow u_{ut} = -\frac{R_4}{R_2} \cdot \frac{1}{1 + \frac{R_1}{R_3} + \frac{R_1}{R_2}} \cdot u_{in} =$$

$$= -\frac{R_4}{R_2} \cdot \frac{R_2 R_3}{R_2 R_3 + R_1(R_2 + R_3)} \Rightarrow$$

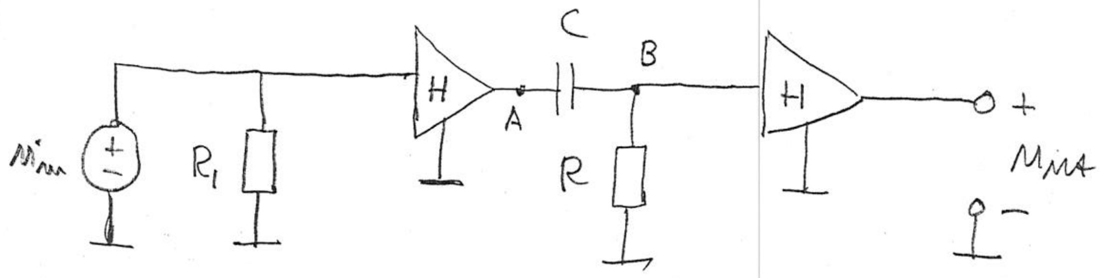
$$\underline{\underline{\frac{u_{ut}}{u_{in}} = -\frac{R_3 R_4}{R_2 R_3 + R_1(R_2 + R_3)}}}$$

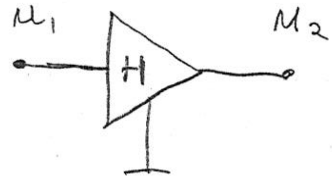
Rin:
$v_A = 0 \Rightarrow R_2$ "parallell med" $R_3 \Rightarrow$

$$u_{in} = R_1 \cdot i_{in} + R_2 // R_3 \cdot i_{in} \Rightarrow$$

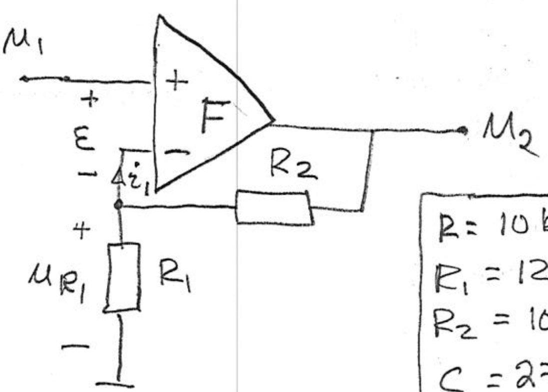
$$R_{in} = \frac{u_{in}}{i_{in}} = R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}$$

3





$\Longleftrightarrow$



$R = 10\,k\Omega$
$R_1 = 12\,k\Omega$
$R_2 = 100\,k\Omega$
$C = 270\,nF$

$F_0 = 200\,000$

$\omega_0'' = 30$ rad/s

$$F(s) = \frac{F_0}{1 + \frac{s}{\omega_0''}} \; ; \; R_{in} = \infty \, , \; R_{ut} = 0 \; ; \text{ Bestäm } H(s):$$

$$H(s) = \frac{u_2}{u_1} \; ; \quad u_2 = F(s) \cdot \varepsilon \; ; \quad \varepsilon = u_1 - u_{R_1} \; ;$$

$$i_1 = 0 \implies u_{R_1} = \frac{R_1}{R_1 + R_2} \cdot u_2 = \beta \cdot u_2 \text{, där } \beta = \frac{R_1}{R_1 + R_2} = 0{,}107$$

$$\implies u_2 = F(s) \cdot (u_1 - \beta \cdot u_2) = F(s) \cdot u_1 - \beta F(s) \cdot u_2 \implies$$

$$u_2 \left(1 + \beta F(s)\right) = F(s) \cdot u_1 \implies H(s) = \frac{F(s)}{1 + \beta \cdot F(s)} =$$

$$= \frac{\frac{F_0}{1 + \frac{s}{\omega_0''}}}{1 + \beta \cdot \frac{F_0}{1 + \frac{s}{\omega_0''}}} = \frac{F_0}{1 + \frac{s}{\omega_0''} + \beta \cdot F_0} = \frac{F_0}{1 + \beta F_0} \cdot \frac{1}{1 + \frac{s}{(1 + \beta F_0) \cdot \omega_0''}} =$$

$$= \frac{9{,}33}{1 + \frac{s}{643 \cdot 10^3}}$$

Bestäm nu $F_{TOT} = \frac{u_{ut}}{u_{in}}$:

$R_{in} = \infty$; $R_{ut} = 0$ hos varje OP ger att de tre stegen ej belastar varandra, vilket ger

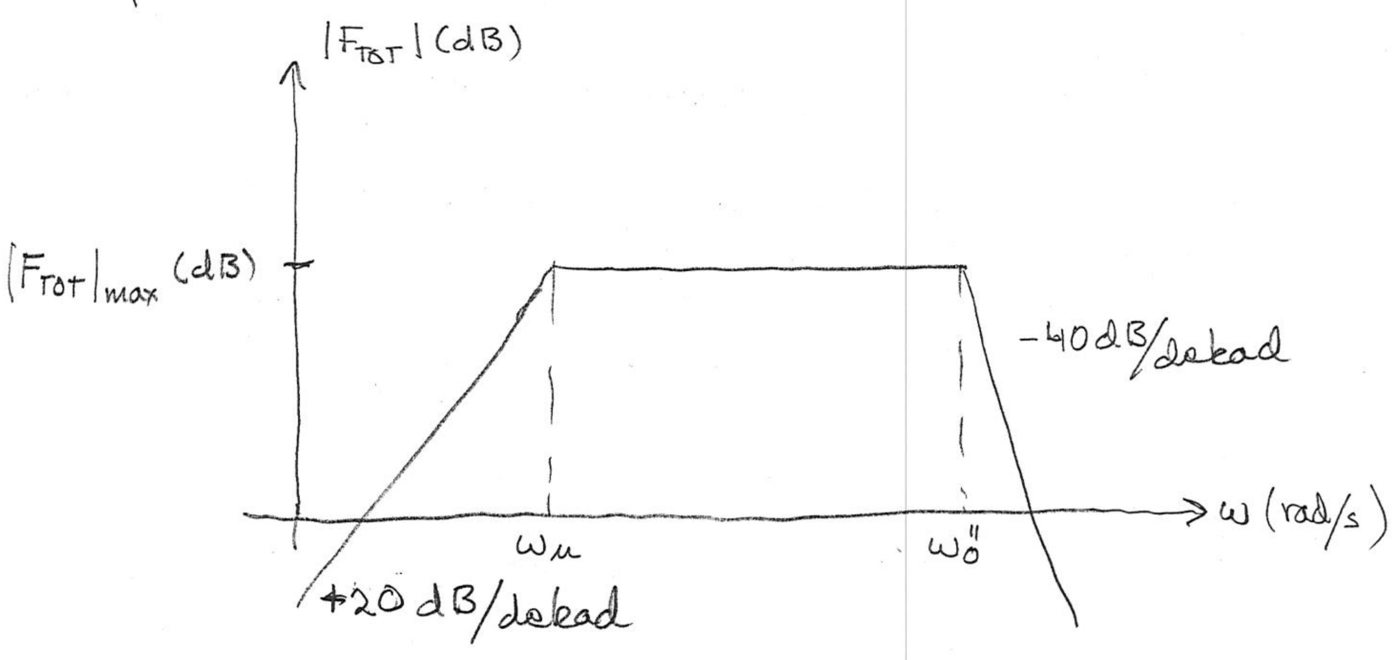
$$F_{TOT}(s) = \frac{u_{ut}}{u_{in}} = \frac{u_{ut}}{v_B} \cdot \frac{v_B}{v_A} \cdot \frac{v_A}{u_{in}},$$

$$v_B = \frac{R}{R + \frac{1}{sC}} \cdot v_A \Rightarrow \frac{v_B}{v_a} = \frac{sRC}{1+sRC} = \frac{\frac{s}{370}}{1 + \frac{s}{370}},$$

så att $F_{TOT}(s) = H(s) \cdot \frac{\frac{s}{370}}{1+\frac{s}{370}} \cdot H(s) =$

$$= \left(\frac{9{,}33}{1 + \frac{s}{640 \cdot 10^3}}\right)^2 \cdot \frac{\frac{s}{370}}{1+\frac{s}{370}}$$

Amplitudfunktion:



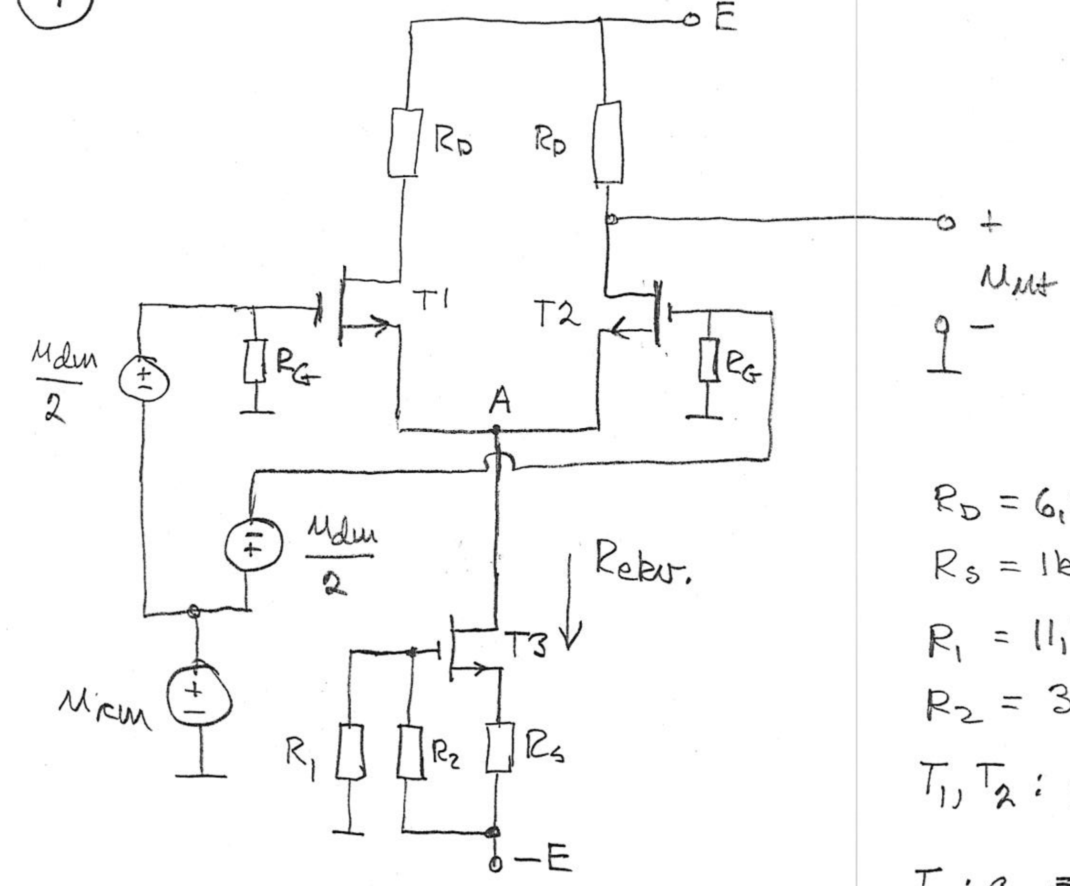
$|F_{TOT}|_{max}$ ges av $370 << \omega << 643 \cdot 10^3$:

$$|F_{TOT}| \approx \left| \left(\frac{9{,}3}{1+0}\right)^2 \cdot \frac{\frac{s}{370}}{\frac{s}{370}} \right| = \underline{\underline{87 \text{ ggr}}} = \underline{\underline{38{,}8 \text{ dB}}}$$

$\omega_u = \underline{\underline{370 \text{ rad/s}}}$

$\omega_ö \text{ (dubbelpol)} = 643 \cdot 10^3 \text{ rad/s} \cdot \sqrt{2^{1/2} - 1} = \underline{\underline{414 \text{ krad/s}}}$

4



$R_D = 6{,}8\,k\Omega$

$R_S = 1\,k\Omega$

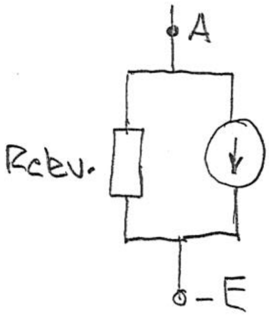
$R_1 = 11{,}4\,k\Omega$

$R_2 = 3{,}6\,k\Omega$

$T_1, T_2: g_m = 3\,mA/V$

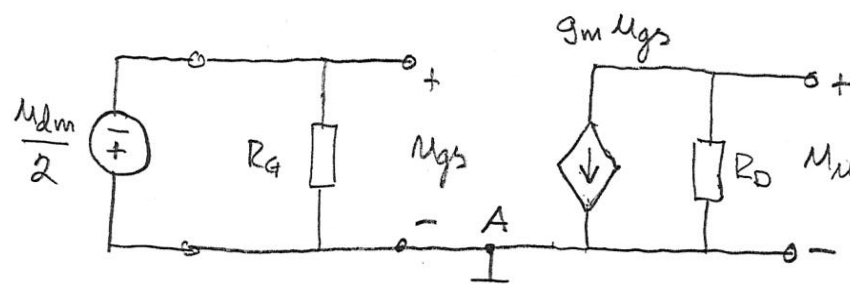
$T_3: g_{m3} = 5\,mA/V;\ r_0 = 30\,k\Omega$

$R_{ekv.}$ är den ekvivalenta signalresistansen hos den strömgenerator som T3 utgör



$$CMRR = \left| \frac{F_{dm}}{F_{cm}} \right|$$

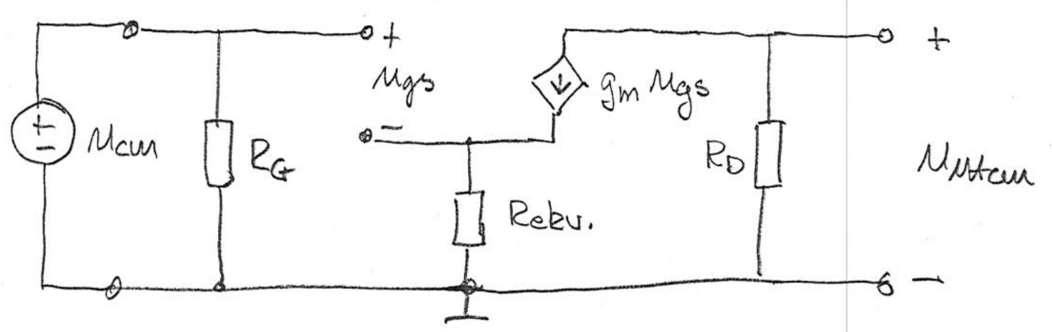
F_{dm} : $u_{cm} = 0$; $v_A = 0$. Betrakta T2



$$\left.\begin{aligned} u_{utdm} &= -g_m u_{gs} \cdot R_D \\ u_{gs} &= -\frac{u_{dm}}{2} \end{aligned}\right\} \Longrightarrow \quad u_{utdm} = -g_m \cdot \left(-\frac{u_{dm}}{2}\right) \cdot R_D \Longrightarrow$$

$$F_{dm} = \frac{u_{utdm}}{u_{dm}} = \underline{\frac{g_m R_D}{2}} = \underline{10{,}2\,ggr}$$

$\underline{F_{cm}}$: Betrakta T2

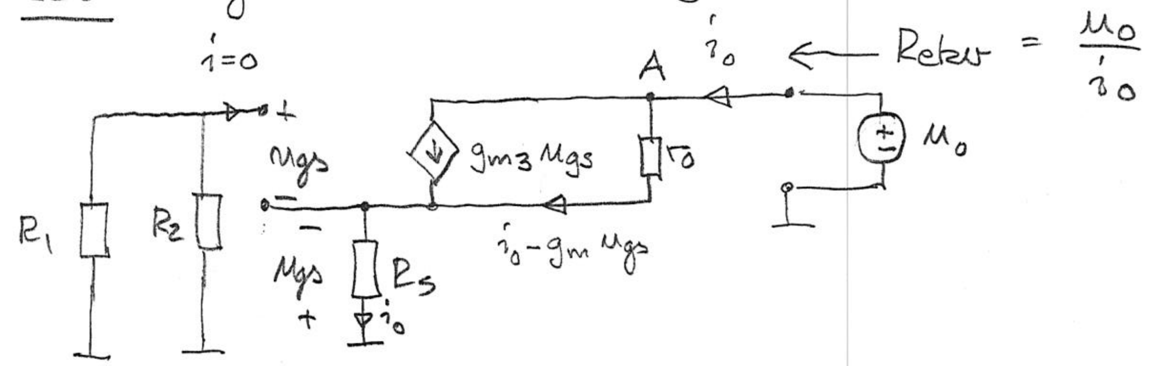


$$u_{utcm} = -g_m u_{gs} \cdot R_D$$

$$u_{cm} = u_{gs} + g_m u_{gs} \cdot R_{ekv.} = (1 + g_m R_{ekv}) \cdot u_{gs} \Rightarrow$$

$$F_{cm} = \frac{u_{utcm}}{u_{cm}} = -\frac{g_m R_D}{1 + g_m R_{ekv.}}$$

$\underline{R_{ekv.}}$ Signalschema strömgenerator



$$\left.\begin{aligned} u_0 &= r_0 (i_0 - g_{m3} u_{gs}) + R_S \cdot i_0 \\ u_{gs} &= -R_S \cdot i_0 \end{aligned}\right\} \Rightarrow u_0 = \left[(1 + g_{m3} R_S) r_0 + R_S\right] \cdot i_0 \Rightarrow$$

$$R_{ekv.} = \frac{u_0}{i_0} = (1 + g_{m3} R_S) \cdot r_0 + R_S = 180\,k\Omega \Rightarrow$$

$$F_{cm} = \underline{-18{,}8 \cdot 10^{-3}\ ggr} \Rightarrow$$

$$CMRR = \left|\frac{F_{dm}}{F_{cm}}\right| = \left|\frac{10{,}2}{-18{,}8 \cdot 10^{-3}}\right| = \underline{\underline{543\,ggr}} = \underline{\underline{54{,}7\,dB}}$$

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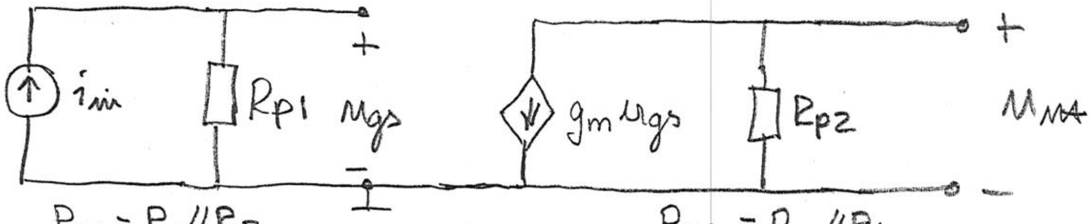
5) Mellanhöga frekvenser betyder

- C_s, C kortsluta
- C_{gs}, C_{gd}, C_b avbrott

Detta ger följande småsignalschema



$R_{p1} = R_1 // R_2$ $\qquad$ $R_{p2} = R_D // R_b$

$$\left.\begin{array}{l} \bullet\ u_{gs} = R_{p1} \cdot i_{in} \\ \bullet\ u_{ut} = -g_m u_{gs} \cdot R_{p2} \end{array}\right\} \Rightarrow \begin{array}{l} u_{ut} = -g_m R_{p1} \cdot R_{p2} \cdot i_{in} \Rightarrow \\ \dfrac{u_{ut}}{i_{in}} = -g_m R_{p1} \cdot R_{p2} \quad (1) \end{array}$$

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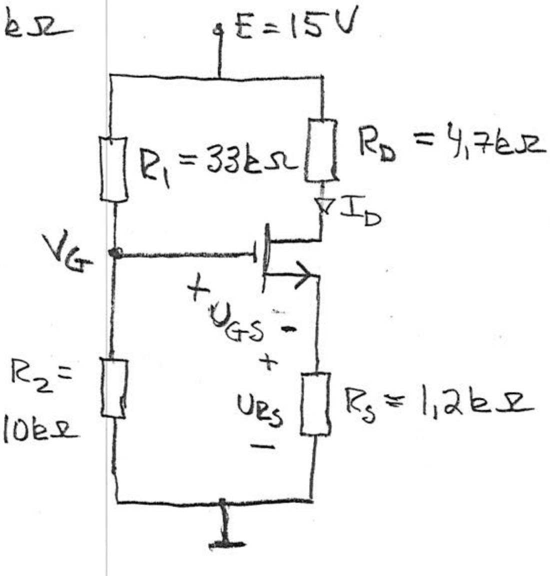
g_m: DC-schema: C_s, C avbrott $i_{in} = 0$ (signalström)

$k = 10\,mA/V^2$ $\quad V_t = 1{,}5\,V$ $\quad R_b = 3{,}9\,k\Omega$



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

- $I_D = \dfrac{U_{RS}}{R_S} = \dfrac{V_G - U_{GS}}{R_S} \quad (3)$

- $V_G = \dfrac{R_2}{R_1 + R_2} \cdot E = \dfrac{10k}{33k + 10k} \cdot 15V =$

$= 3{,}49V \quad (3)$

(2), (3) ger

$$\frac{k}{2}(U_{GS} - V_t)^2 = \frac{V_G - U_{GS}}{R_S} \Rightarrow$$

$$(U_{GS} - V_t)^2 = \frac{2V_G}{k \cdot R_S} - \frac{2U_{GS}}{k \cdot R_S} \Rightarrow U_{GS}^2 - 2V_t \cdot U_{GS} + V_t^2 = \frac{2V_G}{k \cdot R_S} - \frac{2U_{GS}}{k \cdot R_S}$$

$\Rightarrow$

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

$\Rightarrow$ (Utan enheter) tillsammans med (3)

$$U_{GS}^2 + \left(\frac{2}{10m \cdot 1{,}2k} - 2 \cdot 1{,}5 \right) U_{GS} + 1{,}5^2 - \frac{2 \cdot 3{,}49}{10m \cdot 1{,}2k} = 0$$

$\Rightarrow$

$$U_{GS}^2 - 2{,}83 U_{GS} + 1{,}67 = 0 \Rightarrow U_{GS} = \begin{cases} 2V \\ 0{,}831\,V \text{ (strypt)} \end{cases}$$

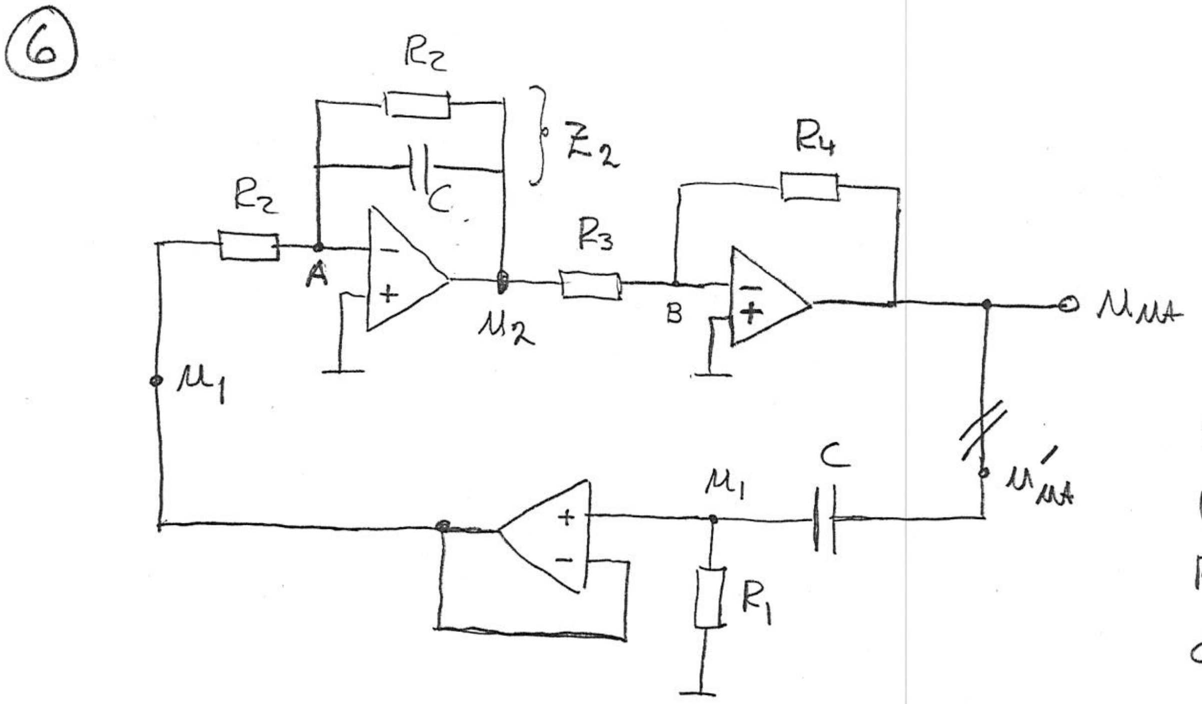
$$\Rightarrow U_{GS} = 2V \Rightarrow I_D = \frac{10mA/V^2}{2}(2V - 1{,}5V)^2 = \underline{1{,}25\,mA}$$

$$\Rightarrow g_m = \sqrt{2 \cdot k \cdot I_D} = \sqrt{2 \cdot 10mA/V^2 \cdot 1{,}25mA} = \underline{5\,mA/V}$$

(1) ger nu $\frac{u_{ut}}{i_{in}} = -5mA/V \cdot (33k\Omega // 10k\Omega) \cdot (4{,}7k\Omega // 3{,}9k\Omega) =$

$$= \underline{\underline{-82\,kV/A}}$$

⑥



$R_1 = 5\,k\Omega$

$R_2 = 10\,k\Omega$

$R_3 = 1\,k\Omega$

$C = 15\,nF$

Sinussvängning: $R_4 = ?$; $f = ?$

Teckna $T(s) = \dfrac{u_{ut}}{u'_{ut}}$

Ideala motkopplade OP: $\begin{cases} \text{inströmmar} = 0 \\ \text{lika potential på ingångar} \end{cases}$

$\Rightarrow$ u_1 ges av spänningsdelning:

$$u_1 = \frac{R_1}{R_1 + \frac{1}{sC}} \cdot u'_{ut} = \frac{sR_1C}{1+sR_1C} \cdot u'_{ut} \quad (1)$$

Nodanalys i A: $\dfrac{V_A - u_1}{R_2} + \dfrac{V_A - u_2}{Z_2} = 0$; $V_A = 0$ $\Rightarrow$

$u_2 = -\dfrac{Z_2}{R_2} \cdot u_1$ (inverterande koppling).

$$Z_2 = \frac{R_2 \cdot \frac{1}{sC}}{R_2 + \frac{1}{sC}} = \frac{R_2}{1+sR_2C} \Rightarrow u_2 = -\frac{1}{1+sR_2C} \cdot u_1 \quad (2)$$

Nodanalys i B:

$$\frac{V_B - u_2}{R_3} + \frac{V_B - u_{ut}}{R_4} = 0 \ ; \quad V_B = 0 \Rightarrow$$

$u_{ut} = -\dfrac{R_4}{R_3} \cdot u_2$ (3) (inverterande koppling)

(1), (2), (3) ger nu att

$$u_{ut} = \left(-\frac{R_4}{R_3}\right)\cdot\left(-\frac{1}{1+sR_2C}\right)\cdot\frac{sR_1C}{1+sR_1C}\cdot u_{ut}' \Rightarrow$$

$$T(s) = \frac{u_{ut}}{u_{ut}'} = \frac{R_4}{R_3}\cdot\frac{sR_1C}{(1+sR_2C)(1+sR_1C)}$$

$$\Rightarrow$$

$$T(j\omega) = \frac{R_4}{R_3}\cdot\frac{j\omega R_1C}{(1+j\omega R_2C)(1+j\omega R_1C)} = \frac{R_4}{R_3}\cdot\frac{j\omega R_1C}{1+j\omega(R_1+R_2)C-\omega^2R_1R_2C^2}$$

Barkhausens svängningsvillkor $T(j\omega)=1 \Rightarrow$

- $1-\omega^2R_1R_2C^2 = 0$ (4)

- $\frac{R_4}{R_3}\cdot\frac{R_1C}{(R_1+R_2)C} = 1$ (5)

(4) $\Rightarrow$ $1-(2\pi f)^2\cdot R_1R_2C^2 = 0 \Rightarrow$

$$f = \frac{1}{2\pi\cdot\sqrt{R_1R_2C^2}} = \underline{\underline{1{,}06\ kHz}}$$

(5) $\Rightarrow$ $R_4 = \frac{R_3(R_1+R_2)\cdot C}{R_1C} = \frac{R_3(R_1+R_2)}{R_1} = \underline{\underline{5\ k\Omega}}$
