Lösningar Elektronik aug 2011

1a. Stor inresistans, liten utresistans

1b. Induktans i anslutningar.

1c. Lödning, virning.

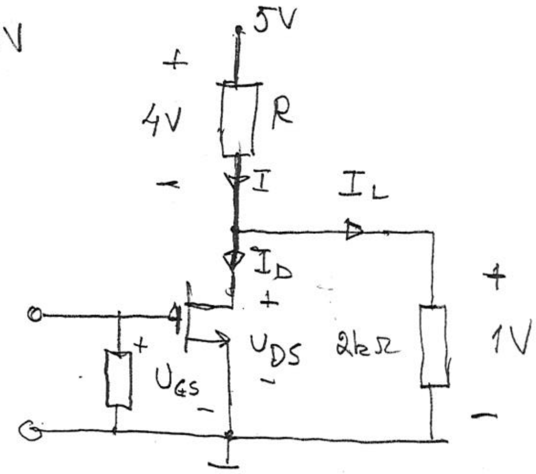
1d. $\beta = \dfrac{2{,}2k\Omega}{2{,}2k\Omega + 82k\Omega} = 0{,}0261$

1e. Gränsfall: $U_{GS} = 4V$, $U_{DS} = 1V$

Område?

$U_{DS} = 1V \quad U_{GS} - V_t = 4V - 1V = 3V$

$U_{DS} < U_{GS} - V_t \Rightarrow$ Triodområdet!



$I_D = k \cdot \left\{ (U_{GS} - V_t) \cdot U_{DS} - \frac{1}{2} U_{DS}^2 \right\} =$

$= 1mA/V^2 \left\{ (4V - 1V) \cdot 1V - \frac{1}{2} \cdot (1V)^2 \right\} = \underline{2{,}5mA}$

$k = 1mA/V^2 \quad V_t = 1V$

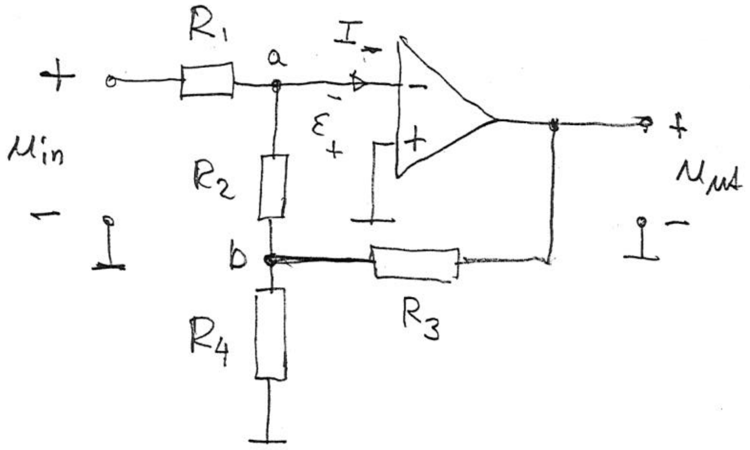
$I_D = \frac{4V}{R} - I_L = \frac{4V}{R} - \frac{1V}{2k\Omega} = \frac{4V}{R} - 0{,}5mA \Rightarrow \frac{4V}{R} - 0{,}5mA = 2{,}5mA \Rightarrow$

$\Rightarrow \underline{\underline{R = 1{,}33k\Omega}}$

1f. $T(j\omega) = 1 \Rightarrow \dfrac{j\omega}{B - \omega^2 + jA\omega} = 1 \Rightarrow$

$\underline{\underline{A = 1}} \qquad B - \omega^2 = 0 \qquad \Rightarrow B = (2\pi \cdot 5000)^2 = \underline{\underline{987 \cdot 10^6}}$

2.



Ideal OP $\Rightarrow$ $I_- = 0$

Motkoppling $\Rightarrow$ $\varepsilon = 0$ $\Rightarrow$ $v_a = 0$

Nodanalys (strömmar ut)

(a) $$\frac{0 - u_{in}}{R_1} + \frac{0 - v_b}{R_2} = 0 \Rightarrow v_b = -\frac{R_2}{R_1} \cdot u_{in} \quad (1)$$

(b) $$\frac{v_b - 0}{R_2} + \frac{v_b}{R_4} + \frac{v_b - u_{ut}}{R_3} \Rightarrow$$

$$\Rightarrow u_{ut} = \left(\frac{R_3}{R_2} + \frac{R_3}{R_4} + 1\right) \cdot v_b \quad (2).$$ (1) och (2) $\Rightarrow$

$$\frac{u_{ut}}{u_{in}} = -\frac{R_2}{R_1} \cdot \left(\frac{R_3}{R_2} + \frac{R_3}{R_4} + 1\right)$$

$v_a = 0 \Rightarrow R_{in} = R_1$

(3)

$$F(s) = \frac{72\cdot 10^{10}\cdot s^2}{(s+120)(s+250)(s+20\cdot 10^3)(s+200\cdot 10^3)} =$$

$$= 72\cdot 10^{10}\cdot \frac{s}{s+120}\cdot\frac{s}{s+250}\cdot\frac{1}{s+20\cdot 10^3}\cdot\frac{1}{s+200\cdot 10^3}$$

HP HP LP LP

$|F|_{max}$: Inträffar vid mellanhöga frekvenser $250 << \omega << 20\cdot 10^3$. Då gäller alltså

$$F(s) \approx 72\cdot 10^{10}\cdot \frac{s\cdot s\cdot 1\cdot 1}{s\cdot s\cdot 20\cdot 10^3\cdot 200\cdot 10^3} = \frac{72\cdot 10^{10}}{4\cdot 10^9} =$$

$= 180$ ggr $= 45{,}1$ dB

Stigtid: Bestäms av $\omega_{\ddot{o}1} = 20\cdot 10^3$ och $\omega_{\ddot{o}2} = 200\cdot 10^3$:

$$\frac{1}{\omega_{\ddot{o}TOT}} \approx 1{,}1\cdot\sqrt{\frac{1}{\omega_{\ddot{o}1}^2}+\frac{1}{\omega_{\ddot{o}2}^2}} = 1{,}1\cdot\sqrt{\frac{1}{(20\cdot 10^3)^2}+\frac{1}{(200\cdot 10^3)^2}} \Rightarrow$$

$\omega_{\ddot{o}TOT} = 18{,}09\cdot 10^3$ rad/s.

$t_r = \frac{2{,}2}{\omega_{\ddot{o}}} = 0{,}122$ ms

Pulsfall: Bestäms av $\omega_{n1} = 120$ och $\omega_{n2} = 250$:

$$P_{rel.} = \frac{\Delta t}{\tau_{TOT}}\cdot 100\% = \Delta t(\omega_{n1}+\omega_{n2})\cdot 100\% =$$

$= 0{,}5\text{ ms}\cdot(120\text{ rad/s} + 250\text{ rad/s})\cdot 100\% = 18{,}5\%$

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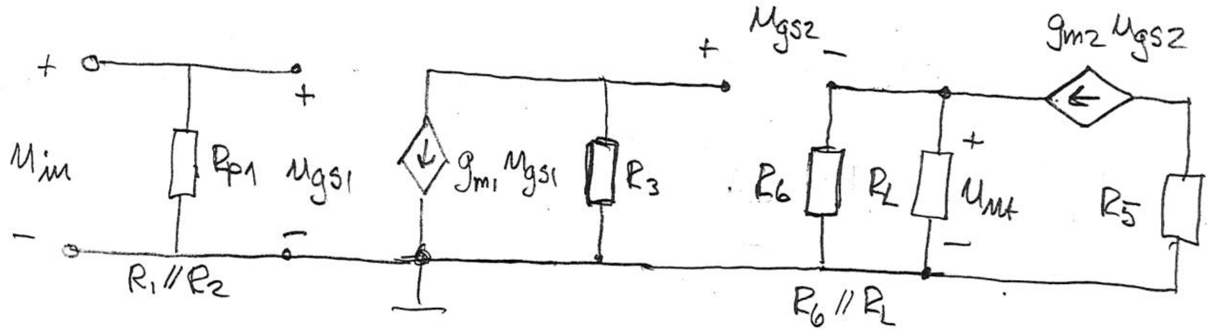
(4) Små signalschema:



$\underline{\frac{u_{ut}}{u_{in}}}$:

$$-R_3 \cdot g_{m1} u_{gs1} = u_{gs2} + R_6 // R_L \cdot g_{m2} u_{gs2} \quad (1)$$

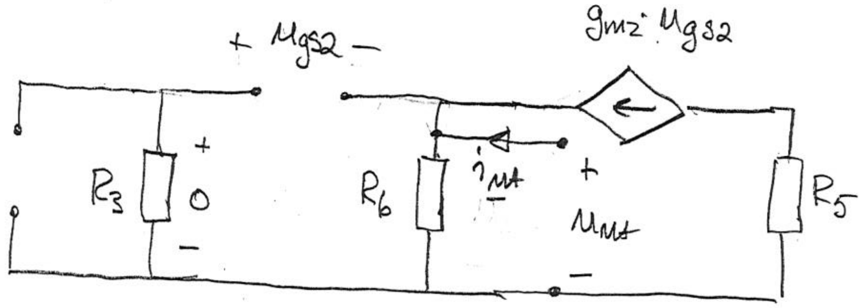
$$u_{gs1} = u_{in} \quad (2)$$

$$u_{ut} = g_{m2} \cdot u_{gs2} \cdot R_6 // R_L \quad (3)$$

(1) och (2) ger $u_{in} = -\dfrac{1 + g_{m2} \cdot R_6 // R_L}{g_{m1} R_3} \cdot u_{gs2} \quad (4)$

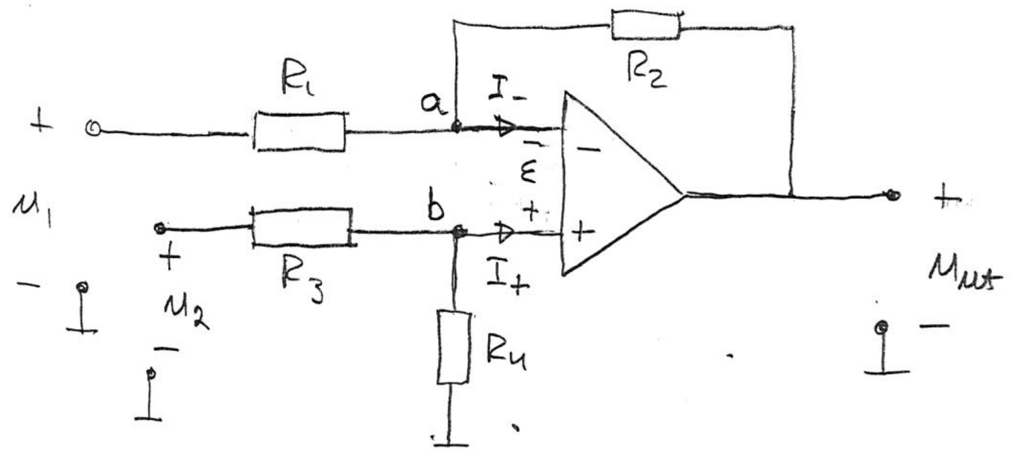
(3) och (4) ger $\dfrac{u_{ut}}{u_{in}} = -g_{m1} R_3 \cdot \dfrac{g_{m2} \cdot R_6 // R_L}{1 + g_{m2} \cdot R_6 // R_L}$

$\underline{R_{ut}}$: $R_{ut} = \left.\dfrac{u_{ut}}{i_{ut}}\right|_{u_{in}=0}$ utan $R_L \Rightarrow u_{gs1} = 0$



$$\left.\begin{aligned} u_{ut} &= (i_{ut} + g_{m2} u_{gs2}) \cdot R_6 \\ u_{gs2} &= -u_{ut} \end{aligned}\right\} \Rightarrow u_{ut}(1 + g_{m2} R_6) = R_6 \cdot i_{ut} \Rightarrow$$

$$R_{ut} = \frac{u_{ut}}{i_{ut}} = \frac{R_6}{1 + g_{m2} R_6}$$



Ideal OP $\Rightarrow I_+ = I_- = 0$

Motkoppling $\Rightarrow \varepsilon = 0$, så att $v_a = v_b$.

$R_1 = 1{,}1\,k\Omega$ $R_2 = 99\,k\Omega$ $R_3 = 99\,k\Omega$ $R_4 = 101\,k\Omega$

Bestäm först u_{ut} som funktion av u_1 och u_2:

Nodanalys (strömmar ut):

a $\quad \dfrac{v_a - u_1}{R_1} + \dfrac{v_a - u_{ut}}{R_2} = 0 \quad (1)$

b $\quad \dfrac{v_b - u_2}{R_3} + \dfrac{v_b}{R_4} = 0 \quad (2)$

$\quad v_a = v_b \quad (3)$

(2) ger $\left(\dfrac{1}{R_3} + \dfrac{1}{R_4}\right) \cdot v_b = \dfrac{u_2}{R_3} \Rightarrow v_b = \dfrac{R_4}{R_3 + R_4} \cdot u_2 \quad (4)$

(1) ger $v_a \cdot \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right) = \dfrac{u_1}{R_1} + \dfrac{u_{ut}}{R_2} \Rightarrow$

$$v_a = \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{u_1}{R_1} + \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{u_{ut}}{R_2} = \frac{R_2}{R_1 + R_2} \cdot u_1 + \frac{R_1}{R_1 + R_2} \cdot u_{ut} \quad (5)$$

(3) ger $\dfrac{R_4}{R_3 + R_4} \cdot u_2 = \dfrac{R_2}{R_1 + R_2} \cdot u_1 + \dfrac{R_1}{R_1 + R_2} \cdot u_{ut} \Rightarrow$

$$u_{ut} = \frac{R_1 + R_2}{R_1} \cdot \left(\frac{R_4}{R_3 + R_4} \cdot u_2 - \frac{R_2}{R_1 + R_2} \cdot u_1\right) \quad (6)$$

DM-förstärkning : $u_2 = \frac{u_{DM}}{2}$, $u_1 = -\frac{u_{DM}}{2}$ $\Rightarrow$

$$u_{ut_{DM}} = \frac{R_1+R_2}{R_1}\left(\frac{R_4}{R_3+R_4} + \frac{R_2}{R_1+R_2}\right)\cdot\frac{u_{DM}}{2} =$$

$$= \frac{100{,}1}{1{,}1}\cdot\left(\frac{101}{101{,}9} + \frac{99}{100{,}1}\right)\cdot\frac{u_{DM}}{2} = 90{,}098\, u_{DM} \Rightarrow$$

$$A_{DM} = \frac{u_{ut\,DM}}{u_{DM}} = \underline{90{,}098 \text{ ggr}}$$

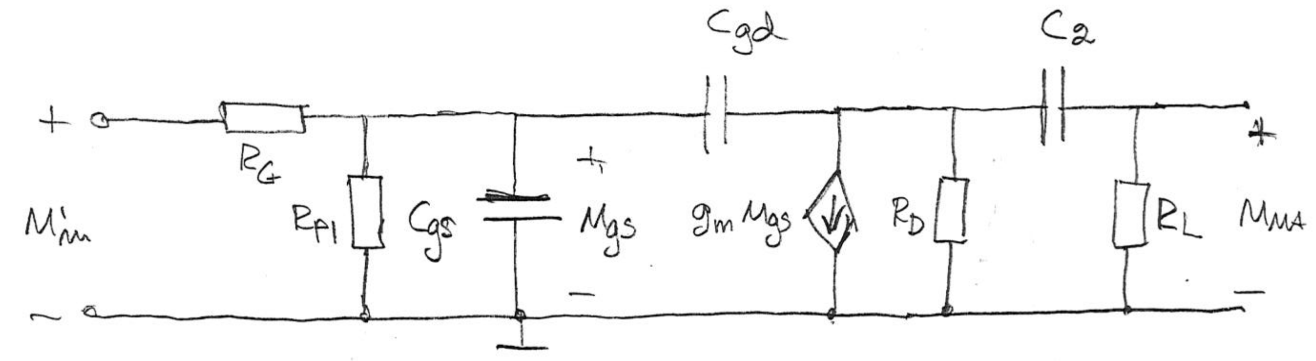
CM-förstärkning : $u_1 = u_2 = u_{CM}$ $\Rightarrow$

$$u_{ut_{CM}} = \frac{R_1+R_2}{R_1}\left(\frac{R_4}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)\cdot u_{CM} = 0{,}19627\cdot u_{CM}$$

$$\Rightarrow A_{CM} = \frac{u_{utCM}}{u_{CM}} = \underline{0{,}19627 \text{ ggr}}$$

$$CMRR = \left|\frac{A_{DM}}{A_{CM}}\right| = \frac{90{,}098}{0{,}19627} = \underline{\underline{459 \text{ ggr}}} = \underline{\underline{53{,}2 \text{ dB}}}$$

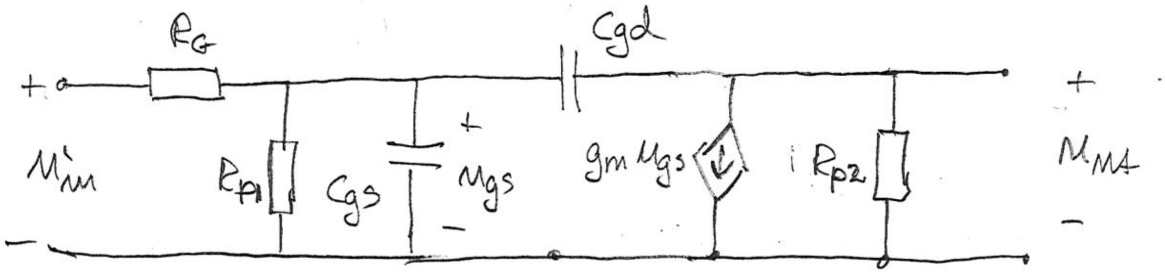
(6.) Småsignalschema



$R_G = 500\Omega$ $R_{P1} = R_1 // R_2 = 200k\Omega$ $R_D = 4k\Omega$ $R_L = 5k\Omega$

$C_2 = 250nF$ $g_m = 50mA/V$ $C_{gs} = 30pF$ $C_{gd} = 3pF$ $r_0 = \infty$

Höga frekvenser: $\frac{1}{\omega C_2} \approx 0$ $R_{P2} = R_D // R_L = 2{,}22k\Omega$

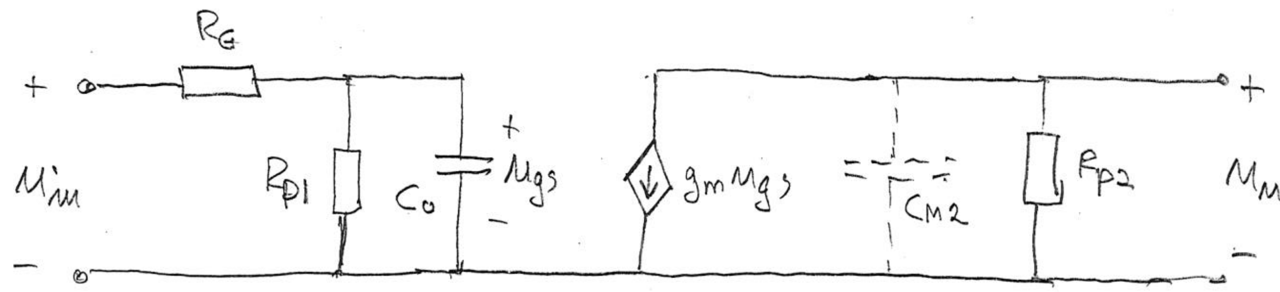


C_{gd} delas upp med Millers sats:

$C_{M1} = (1-k)\cdot C_{gd}$ $C_{M2} = \left(1-\frac{1}{k}\right)\cdot C_{gd}$, där

$k \approx \frac{M_{ut}}{M_{gs}} = \frac{-R_{P2}\cdot g_m M_{gs}}{M_{gs}} = -R_{P2}\cdot g_m = -2{,}22k\Omega\cdot 50mA/V = -111.$

$\Rightarrow C_{M1} = 112\cdot 3pF = 336pF$ $C_{M2} \approx 1{,}01\cdot 3pF = 3{,}03pF$ (försummas)



$C_0 = C_{gs} + C_{M1} = 30pF + 336pF = 366pF$

$R_{p1} >> R_G \Rightarrow$

$$u_{gs} \approx \frac{\frac{1}{sC_0}}{\frac{1}{sC_0} + R_G} \cdot u_{in} = \frac{1}{1 + sR_GC_0} \cdot u_{in}$$

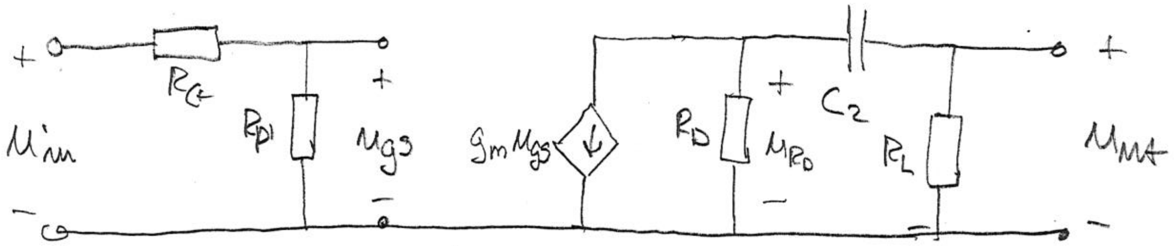
$$u_{ut} = -R_{p2} \cdot g_m u_{gs} = -\frac{g_m R_{p2}}{1 + sR_GC_0} \cdot u_{in} \Rightarrow$$

$$\frac{u_{ut}}{u_{in}} = -\frac{g_m R_{p2}}{1 + sR_GC_0}$$

Den övre gränsvinkelfrekvensen blir då

$$\omega_ö = \frac{1}{R_GC_0} = \frac{1}{500\Omega \cdot 366pF} = \underline{\underline{5{,}46\ Mrad/s}} \Rightarrow \underline{\underline{f_ö = 870\ kHz}}$$

<u>Låga frekvenser</u>: $\frac{1}{\omega C_{gs}} \approx \infty$, $\frac{1}{\omega C_{gd}} \approx \infty$, $\frac{1}{\omega C_2} > 0$



$$u_{gs} = \frac{R_{p1}}{R_{p1} + R_G} \cdot u_{in} = 0{,}9975 \cdot u_{in} \approx u_{in}$$

$$u_{ut} = \frac{R_L}{R_L + \frac{1}{sC_2}} \cdot u_{R_D} = \frac{sR_LC_2}{1 + sR_LC_2} \cdot u_{R_D} =$$

$$= \frac{sR_LC_2}{1 + sR_LC_2}\left(-g_m u_{gs} \cdot R_D // \left(R_L + \frac{1}{sC_2}\right)\right) = -\frac{g_m u_{gs} \cdot sR_LC_2}{1 + sR_LC_2} \cdot \frac{R_D \cdot \left(R_L + \frac{1}{sC_2}\right)}{R_D + R_L + \frac{1}{sC_2}} =$$

$$= -\frac{g_m u_{gs} \cdot sR_LC_2 \cdot R_D \cdot \cancel{(1 + sR_LC_2)}}{\cancel{(1 + sR_LC_2)} \cdot (1 + s(R_L + R_D)C_2)} \quad (HP) \Rightarrow$$

$$\omega_n = \frac{1}{(R_D + R_L)C_2} = \underline{\underline{444\ rad/s}} \Rightarrow \underline{\underline{f_n = 70{,}7\ Hz}}$$
