Lösningar Elektronik april 2015

1a. $150°C - T_a = 1W \cdot 62{,}5°C/W \Rightarrow$

$$T_{a_{max}} = 87{,}5°C$$

1b. i) Resistorns induktans och kapacitans påverkar kretsen.

ii) Bruset i resistorn spelar roll vid låga signalnivåer.

1c. • NTC-motstånd, temperaturmätning
• Fotomotstånd, mätning av ljusstyrka
• Varistor, skydd mot spänningstransienter.

1d. $V_{GS} = 3{,}5V \Rightarrow I_D = \frac{4mA/V^2}{2} \cdot (3{,}5V - 1{,}5V)^2 = 8mA$

$V_{DS} = 11{,}5V > V_{GS} - V_t$. Strömmättnad!

$$R_S = \frac{-3{,}5V-(-8V)}{8mA} = 562{,}5\Omega$$

1e. $I_{Z_{max}} = \frac{5W}{5{,}6V} = 893mA$; $I_L = \frac{5{,}6V}{56\Omega} = 100mA$

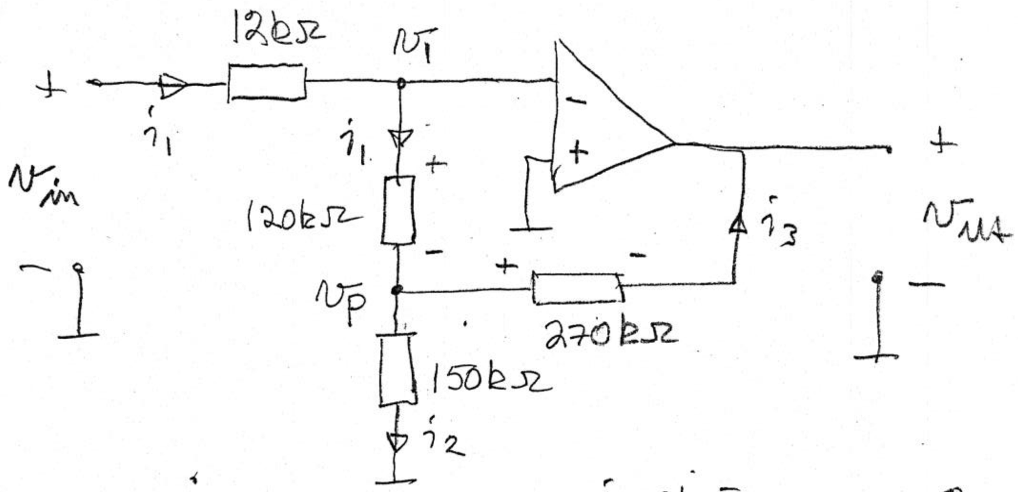
$$u_{I_{max}} = 5{,}6V + 27\Omega(893mA + 100mA) = 32{,}4V$$

$$u_{I_{min}} = 5{,}6V + 27\Omega \cdot 100mA = 8{,}3V$$

1f. $s^2 + 5as + 16 = 0 \Rightarrow s = -2{,}5a \pm \sqrt{6{,}25a^2 - 16}$

dubbelpol $\Rightarrow$ $6{,}25a^2 = 16 \Rightarrow a = 1{,}6$

2.



ideal motkopplad OP ⇒ • inströmmar = 0
• $v_1 = 0$

$\Rightarrow$ • $v_{ut} = v_p - 270\,k\Omega \cdot i_3$ (1)

• $i_3 = i_1 - i_2$ (2)

• $v_p = v_1 - 120\,k\Omega \cdot i_1 = -120\,k\Omega \cdot i_1$ (3)

• $i_1 = \dfrac{v_{in} - v_1}{12\,k\Omega} = \dfrac{0{,}085\,V}{12\,k\Omega} = \underline{7{,}0833\,\mu A}$

• $i_2 = \dfrac{v_p}{150\,k\Omega}$ (4)

(3) ger $v_p = -120\,k\Omega \cdot 7{,}0833\,\mu A = \underline{-0{,}85\,V}$

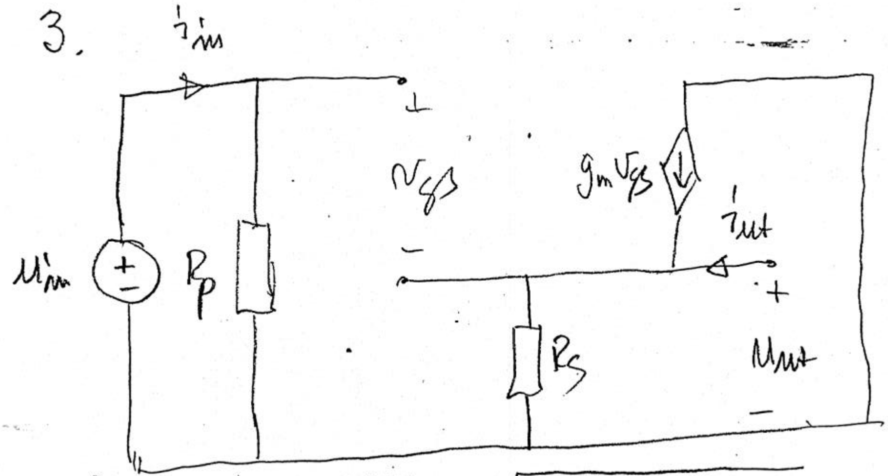
(4) ger $i_2 = \dfrac{-0{,}85\,V}{150\,k\Omega} = \underline{-5{,}667\,\mu A}$

(2) ger $i_3 = 7{,}0833\,\mu A - (-5{,}667\,\mu A) = 12{,}75\,\mu A$

$\Rightarrow v_{ut} = -0{,}85\,V - 270\,k\Omega \cdot 12{,}75\,\mu A = \underline{\underline{-4{,}29\,V}}$

$v_1 = 0 \Rightarrow R_{in} = \dfrac{v_{in}}{i_1} = \dfrac{12\,k\Omega \cdot i_1}{i_1} = \underline{\underline{12\,k\Omega}}$

3.



$$g_m = \sqrt{2k \cdot I_D} = \sqrt{2 \cdot 2\,mA/V^2 \cdot 4\,mA} = 4\,mA/V$$

$\underline{\dfrac{u_{ut}}{u_{in}}}$

$$u_{ut} = g_m R_s \cdot v_{gs}$$

$$u_{in} = v_{gs} + u_{ut} = (1 + g_m R_s)\, v_{gs} \quad \Rightarrow$$

$$\frac{u_{ut}}{u_{in}} = \frac{g_m R_s}{1 + g_m R_s} = \frac{4\,mA/V \cdot 2\,k\Omega}{1 + 4\,mA/V \cdot 2\,k\Omega} = \frac{8}{9} = \underline{0{,}89}$$

$\underline{R_{in}}$ $\quad u_{in} = R_p \cdot i_{in}$

$$R_{in} = \frac{u_{in}}{i_{in}} = R_p = 100\,k\Omega // 220\,k\Omega = \underline{68{,}8\,k\Omega}$$

$$R_{ut} = \frac{u_{ut}}{i_{ut}}\bigg|_{v_{in}=0} ; \quad v_{in} = 0 \Rightarrow u_{R_S} = -v_{gs}$$

→

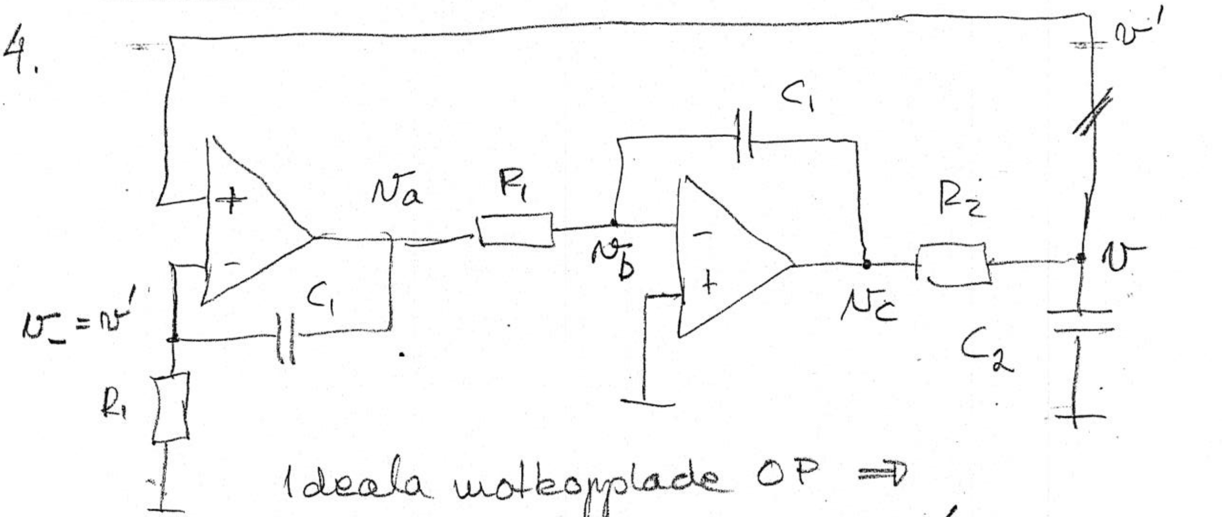
$\underline{R_{ut}}$ $\quad R_{ut} = \frac{u_{ut}}{i_{ut}}\Big|_{v_{in}} = 0$

$$v_{in} = 0 \Rightarrow u_{ut} = -v_{gs} \Leftrightarrow v_{gs} = -u_{ut}$$

$$u_{ut} = R_S \cdot (i_{ut} + g_m v_{gs}) = R_S i_{ut} - g_m R_S u_{ut} \Rightarrow$$

$$R_{ut} = \frac{u_{ut}}{i_{ut}} = \frac{R_S}{1+g_m R_S} = \frac{2k\Omega}{1+4mA/V \cdot 2k\Omega} = \underline{\underline{222\Omega}}$$

4.



Ideala motkopplade OP $\Rightarrow$

• inströmmar = 0 $\quad v_b = 0, \; v_- = v'$

Nodanalys $\underline{v'}$ $\quad \frac{v'}{R_1} + \frac{v' - v_a}{\frac{1}{sC_1}} = 0 \quad \Rightarrow$

$$v_a = \frac{1 + sR_1C_1}{sR_1C_1} \cdot v' \quad (1)$$

$\underline{v_b}$ $\quad \frac{v_b - v_a}{R_1} + \frac{v_b - v_c}{\frac{1}{sC_1}} = 0 \quad ; \quad v_b = 0 \Rightarrow$

$$v_c = -\frac{1}{sR_1C_1} \cdot v_a \quad (2)$$

$\underline{v}$ $\quad \frac{v - v_c}{R_2} + \frac{v}{\frac{1}{sC_2}} = 0 \quad \Rightarrow \quad v = \frac{1}{1 + sR_2C_2} \cdot v_c \quad (3)$

(1), (2), (3) ger

$$T(s) = \frac{v}{v'} = -\frac{1+sR_1C_1}{s^2R_1^2C_1^2(1+sR_2C_2)} \Rightarrow$$

$$T(j\omega) = -\frac{1+j\omega R_1C_1}{-\omega^2R_1^2C_1^2(1+j\omega R_2C_2)}$$

$$T(j\omega) = 1 \Rightarrow \omega^2R_1^2C_1^2 = 1 \; ; \; R_1C_1 = R_2C_2$$

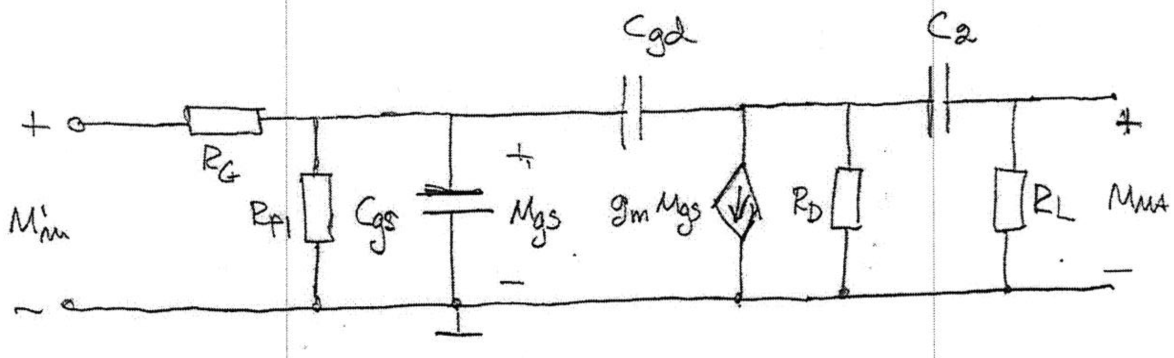
$f = 10\,kHz \Rightarrow$

$$2\pi \cdot 10^4 \cdot 10^4 \cdot C_1 = 1 \Rightarrow \underline{\underline{C_1 = 1{,}59\,nF}}$$

$$R_2 = \frac{R_1C_1}{C_2} = \frac{10^4 \cdot 1{,}59 \cdot 10^{-9}}{10 \cdot 10^{-9}} = \underline{\underline{1{,}59\,k\Omega}}$$

5.

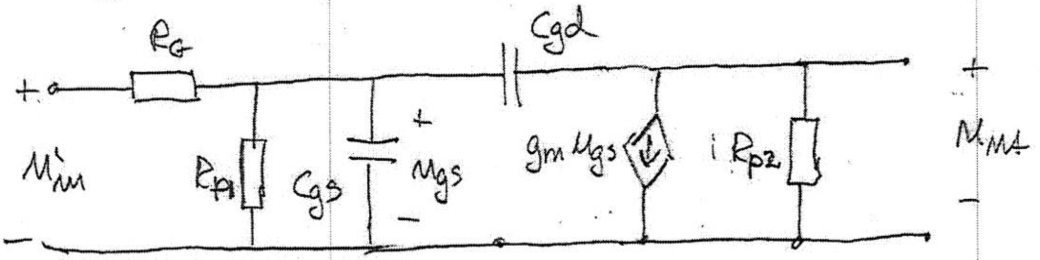
Småsignalschema



$R_G = 500\,\Omega$ $R_{p1} = R_1 // R_2 = 200\,k\Omega$ $R_D = 4\,k\Omega$ $R_L = 5\,k\Omega$

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

Höga frekvenser: $\frac{1}{\omega C_2} \approx 0$ $R_{p2} = R_D // R_L = 2{,}22\,k\Omega$

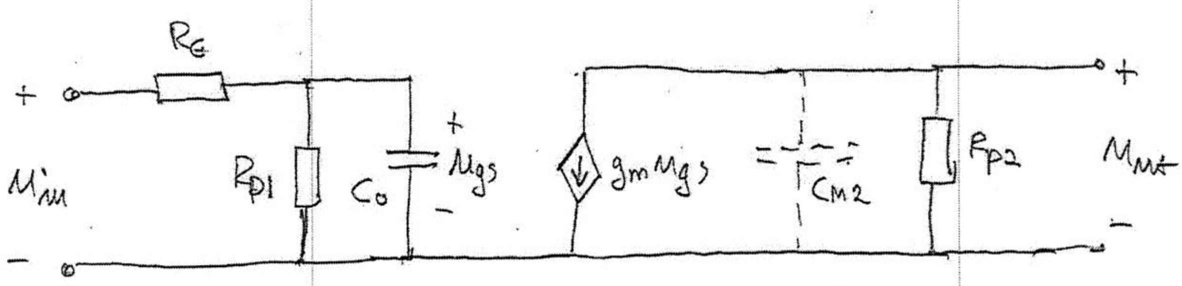


C_{gd} delas upp med Millers sats:

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

$k \approx \frac{u_{ut}}{u_{gs}} = \frac{-R_{p2}\cdot g_m u_{gs}}{u_{gs}} = -R_{p2}\cdot g_m = -2{,}22\,k\Omega\cdot 50\,mA/V = -111,$

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



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

$R_{p1} >> R_G \Rightarrow$

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

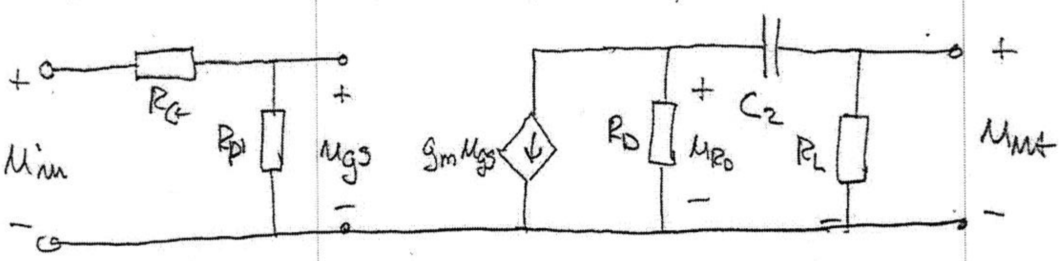
$$u_{ut} = - R_{p2} \cdot g_m u_{gs} = - \frac{g_m R_{p2}}{1 + sR_GC_0} \cdot u_{in} \Rightarrow$$

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

Den övre gränsvinkelfrekvensen blir då

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

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



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

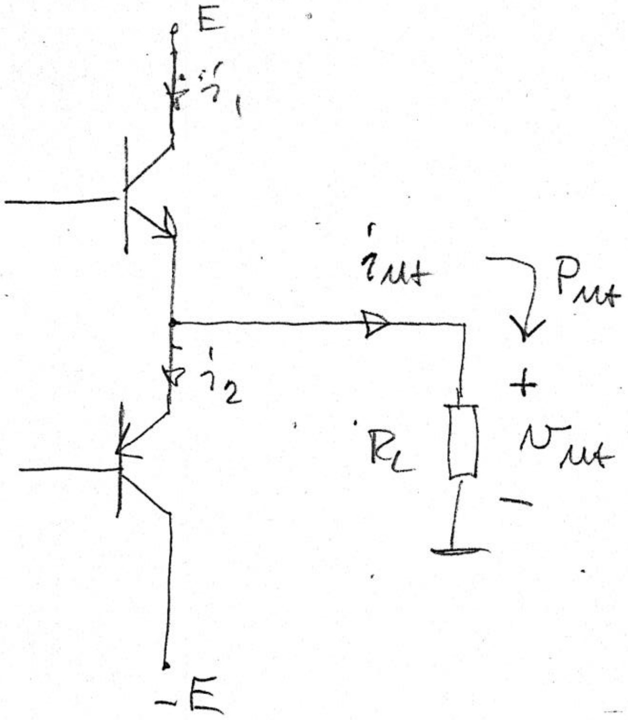
$$u_{ut} = \frac{R_L}{R_L + \frac{1}{sC_2}} \cdot u_{R_D} = \frac{sR_LC_2}{1 + sR_LC_2} \cdot u_{R_D} =$$

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

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

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

6.



$E = 12V$

$R_L = 4\Omega$

$$R_L \cdot \left(\frac{\hat{i}_{ut}}{\sqrt{2}}\right)^2 = 13{,}5W \Rightarrow \hat{i}_{ut} = \sqrt{2} \cdot \sqrt{\frac{13{,}5}{4}}\, A = 2{,}598A$$

$$\Rightarrow P_{in} = 2 \cdot E \cdot \frac{\hat{i}_{ut}}{\pi} = 2 \cdot 12V \cdot \frac{2{,}598A}{\pi} = 19{,}848W \Rightarrow$$

Verkningsgraden $\eta = \dfrac{13{,}5W}{19{,}848W} = \underline{\underline{68{,}02\%}}$

Förlusteffekt $P_F = P_{in} - 13{,}5W = \underline{\underline{6{,}35W}}$

Max uteffekt om $\hat{v}_{ut} = E = 12V \Rightarrow$

$$P_{ut\,max} = \frac{\left(\frac{12V}{\sqrt{2}}\right)^2}{4\Omega} = \underline{\underline{18W}}$$