Lösningar elektronik maj 2013

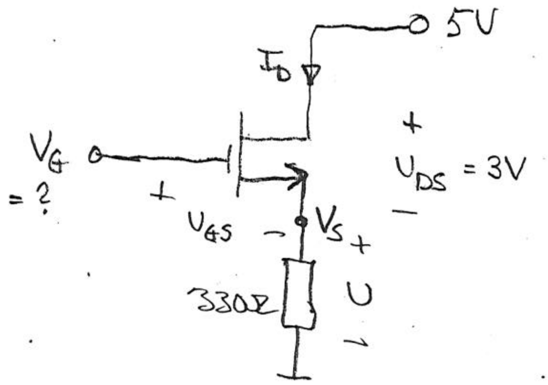
1a.
- Massamotstånd lämpliga vid höga frekvenser
- Metallfilmsmotstånd har induktans och är olämpliga vid höga frekvenser

1b. Filterkondensator:
- stabil kapacitans
- små förluster

Kopplingskondensator:
- låg impedans över
- stort frekvensområde

1c Vanliga sekundärbatterier:
- Blyackumulator
- Ni-Cd-ackumulator

1d.



$k = 4mA/V^2$
$V_t = 1V$

- $V_G = U + U_{GS}$, $U = 5V - 3V = 2V \Rightarrow I_D = \frac{2V}{330\Omega} = \underline{6{,}061mA}$

- Antag strömmättnad. U_{GS} ges av

$$I_D = \frac{k}{2}(U_{GS} - V_t)^2 \Rightarrow 6{,}061mA = \frac{4mA/V^2}{2}(U_{GS} - 1V)^2 \Rightarrow$$

$$U_{GS} - 1V = \pm 1{,}74V \Rightarrow U_{GS} = \begin{cases} 2{,}74V \\ (-0{,}74V) \text{ strypt} \end{cases}$$

Strömmättnad? $U_{DS} = 3V$ $U_{GS} - V_t = 1{,}74V$ Ja!

$$\Rightarrow V_G = U + U_{GS} = 2V + 2{,}74V = \underline{\underline{4{,}74V}}$$

1e Icke-oscillatoriskt: reella poler

$s^2 + 36s + 24a = 0 \Rightarrow s = -18 \pm \sqrt{18^2 - 24a}$

reella poler om $24a \leq 18^2 \Rightarrow \underline{\underline{a \leq 13{,}5}}$

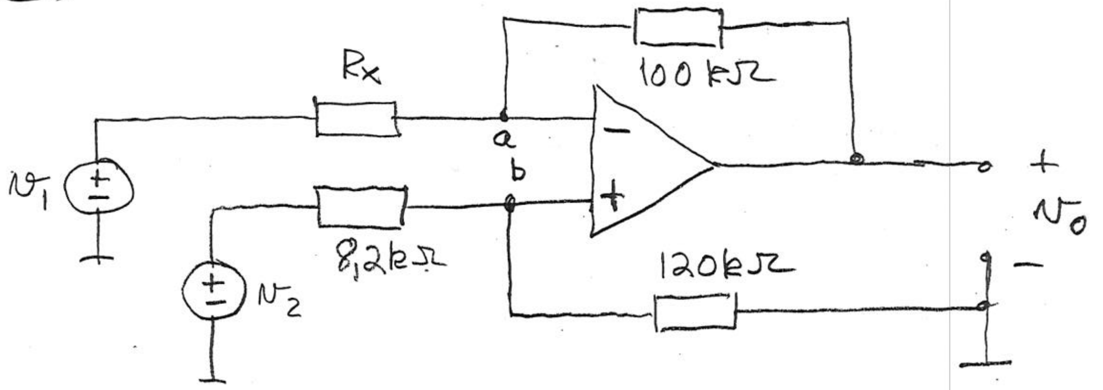
1F $I_D = \frac{k}{2}(U_{GS} - V_t)^2 \Rightarrow I_D = \frac{k}{2}(U_{GS} + 4V)^2$

$U_{GS} = 0 \Rightarrow I_D = 8mA \Rightarrow$

$8mA = \frac{k}{2} \cdot (0 + 4V)^2 = k \cdot 8V^2 \Rightarrow \underline{\underline{k = 1mA/V^2}}$

$I_D \geq 0$, $V_t < 0 \Rightarrow$ <u>N-kanals utarmnings MOSFET</u>

2.



Ideal motkopplad OP $\Rightarrow$ • $v_a = v_b$
• inströmmar = 0

Nodanalys:

$$\frac{v_b - v_2}{8{,}2k\Omega} + \frac{v_b}{120k\Omega} = 0 \Rightarrow v_b\left(\frac{1}{8{,}2k\Omega} + \frac{1}{120k\Omega}\right) = \frac{v_2}{8{,}2k\Omega} \Rightarrow$$

$$v_b\left(1 + \frac{8{,}2k\Omega}{120k\Omega}\right) = v_2 \Rightarrow v_b = \frac{120k\Omega}{120k\Omega + 8{,}2k\Omega} \cdot v_2 = \underline{0{,}936 \cdot v_2}$$

$$\frac{v_a - v_1}{R_x} + \frac{v_a - v_0}{100k\Omega} = 0 \Rightarrow v_a\left(\frac{1}{R_x} + \frac{1}{100k}\right) = \frac{v_0}{100k} + \frac{v_1}{R_x}$$

$$\Rightarrow v_0 = v_a\left(\frac{100k}{R_x} + 1\right) - \frac{100k}{R_x} \cdot v_1 \; ; \; v_a = v_b \Rightarrow$$

$$v_0 = 0{,}936 \cdot \left(\frac{100k}{R_x} + 1\right) v_2 - \frac{100k}{R_x} \cdot v_1 \Rightarrow$$

$$0{,}936 \cdot \left(\frac{100k}{R_x} + 1\right) = \frac{100k}{R_x} \Rightarrow$$

$$100k\Omega = 0{,}936\left(100k\Omega + R_x\right) \Rightarrow$$

$$100k\Omega = 93{,}6k\Omega + 0{,}936 R_x \Rightarrow \underline{\underline{R_x = 6{,}83 k\Omega}}$$

$$k = \frac{100k\Omega}{6{,}83k\Omega} = \underline{\underline{14{,}6}}$$

3. $$F(s) = \frac{10^{11} \cdot s^2}{(s^2+300s+2\cdot 10^4)(s+12000)(s+25000)}$$

Poler $s = \begin{cases} -12000 \\ -25000 \end{cases}$

$$s^2+300s+2\cdot 10^4 = 0 \Rightarrow s = -150 \pm \sqrt{150^2 - 2\cdot 10^4} =$$

$$= s = -150 \pm 50 = \begin{cases} -200 \\ -100 \end{cases} \Rightarrow$$

$$F(s) = \frac{10^{11} s^2}{(s+100)(s+200)(s+12000)(s+25000)}$$

$\Rightarrow$ $\omega_{M1} = 100$ rad/s $\omega_{M2} = 200$ rad/s

$\omega_{\ddot{o}1} = 12000$ rad/s $\omega_{\ddot{o}2} = 25000$ rad/s

$$\Rightarrow \frac{1}{\omega_{\ddot{o}TOT}} = 1{,}1 \cdot \sqrt{\frac{1}{12000^2} + \frac{1}{25000^2}} \Rightarrow \omega_{\ddot{o}TOT} = \underline{9{,}83 \text{ krad/s}}$$

Stigtid : $t_r = \frac{2{,}2}{\omega_{\ddot{o}TOT}} = \underline{\underline{0{,}224 \text{ ms}}}$

Relativt pulsfall :

$$P_f = \frac{\Delta t}{\tau_{TOT}} \cdot 100\% = \Delta t \cdot (\omega_{M1} + \omega_{M2}) \cdot 100\% =$$

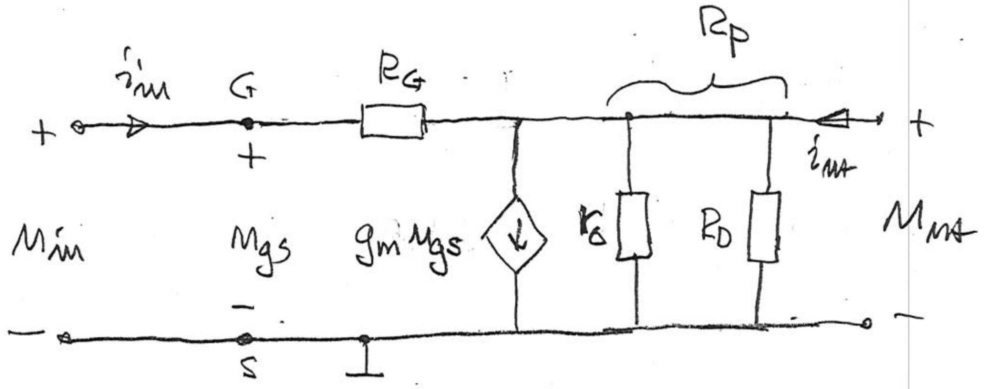
$$= 0{,}6 \cdot 10^{-3} (100+200) \cdot 100\% = \underline{\underline{18\%}}$$

$|F|_{max}$: Tag $200 << s << 12000$:

$$\Rightarrow F(s) \approx \frac{10^{11} s^2}{s \cdot s \cdot 12000 \cdot 25000} = 333 \Rightarrow$$

$$\underline{\underline{|F|_{max} = 333 \text{ ggr} = 50{,}5 \text{ dB}}}$$

4. Småsignalschema



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

- $u_{ut} = R_p(i_{in} - g_m u_{gs})$
- $u_{gs} = u_{in}$
- $i_{in} = \frac{u_{in} - u_{ut}}{R_G}$

$\Rightarrow$

$$u_{ut} = R_p \cdot \left(\frac{u_{in} - u_{ut}}{R_G} - g_m u_{in} \right) \Rightarrow$$

$$R_G u_{ut} = R_p u_{in} - R_p u_{ut} - g_m R_p R_G u_{in} \Rightarrow$$

$$\frac{u_{ut}}{u_{in}} = \frac{R_p(1 - g_m R_G)}{R_G + R_p} \quad ; \quad R_p = r_o // R_D = 8{,}246\ k\Omega \quad g_m = 0{,}25 mA/V,\ R_G = 10 M\Omega \Rightarrow$$

$$\frac{u_{ut}}{u_{in}} = \underline{\underline{-2{,}06\ ggr}}$$

R_{in}

$$R_{in} = \frac{u_{in}}{i_{in}} \ ; \ u_{in} = R_G \cdot i_{in} + R_p(i_{in} - g_m u_{gs}) \Rightarrow$$

$$u_{in} = R_G i_{in} + R_p i_{in} - g_m R_p u_{in} \Rightarrow$$

$$R_{in} = \frac{u_{in}}{i_{in}} = \frac{R_G + R_p}{1 + g_m R_p} = \underline{\underline{3{,}27\ M\Omega}}$$

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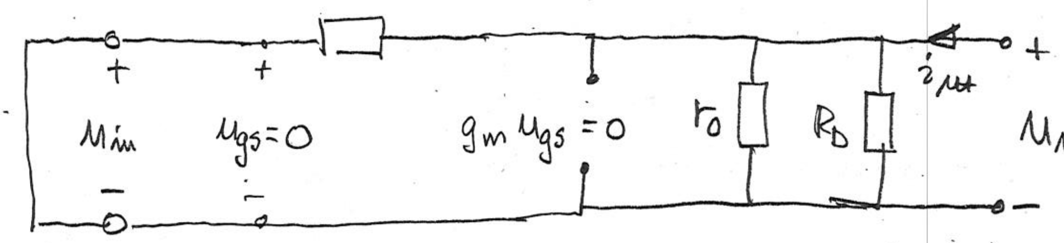
⑥

$\underline{R_{ut}}$ $\quad R_{ut} = \dfrac{u_{ut}}{i_{ut}}\Bigg|_{u_{in}=0}$

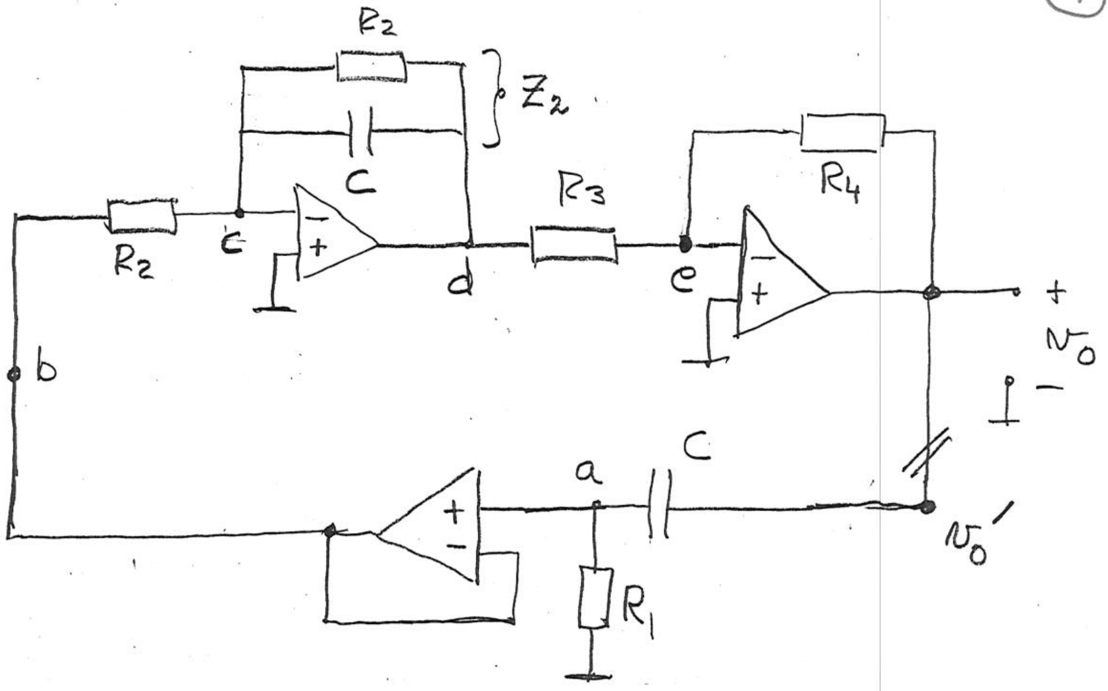
$u_{in} = 0 \Rightarrow u_{gs} = 0 \Rightarrow g_m u_{gs} = 0 \Rightarrow$ (se fig.)

$u_{ut} = (R_G // r_0 // R_D) \cdot i_{ut} \Rightarrow$

$R_{ut} = R_G // r_0 // R_D = \underline{\underline{8{,}24\,k\Omega}}$



5.



- Ideala motkopplade OP ⟹ inströmmar = 0

$v_a = v_b$, $v_c = v_e = 0$

- Nodanalys för att bestämma $T(s) = \dfrac{v_0}{v_0'}$

$\underline{a}$ • $\dfrac{v_a}{R_1} + sC(v_a - v_0') \Rightarrow v_a\left(\dfrac{1}{R_1} + sC\right) = sC\, v_0' \Rightarrow$

• $v_a = \dfrac{sR_1C}{1+sR_1C} \cdot v_0'$ (1)

• $v_b = v_a$ (spänningsföljare)

$\underline{c}$ • $v_c = 0 \Rightarrow \dfrac{0 - v_b}{R_2} + \dfrac{0 - v_d}{Z_2} = 0 \Rightarrow$

$v_d = -\dfrac{Z_2}{R_2} \cdot v_b$ (2)

$Z_2 = R_2 // \dfrac{1}{sC} = \dfrac{R_2 \cdot \frac{1}{sC}}{R_2 + \frac{1}{sC}} = \dfrac{R_2}{1+sR_2C}$. (2) ger då

$v_d = -\dfrac{1}{1+sR_2C} \cdot v_b = -\dfrac{1}{1+sR_2C} \cdot v_a$ (3)

e $v_e = 0 \Rightarrow$

$$\frac{0 - v_d}{R_3} + \frac{0 - v_0}{R_4} = 0 \Rightarrow v_0 = -\frac{R_4}{R_3} \cdot v_d \quad (4)$$

(1), (3), (4) ger

$$v_0 = -\frac{R_4}{R_3} \cdot \left(-\frac{1}{1+sR_2C}\right) \cdot \frac{sR_1C}{1+sR_1C} \cdot v_0' \quad \frac{sR_4R_1C}{R_3(1+sR_2C)(1+sR_1C)} \cdot v_0'$$

$$\Rightarrow T(s) = \frac{v_0}{v_0'} = \frac{s \cdot \frac{R_4R_1}{R_3} \cdot C}{s^2R_1R_2C^2 + s(R_1+R_2)C + 1}$$

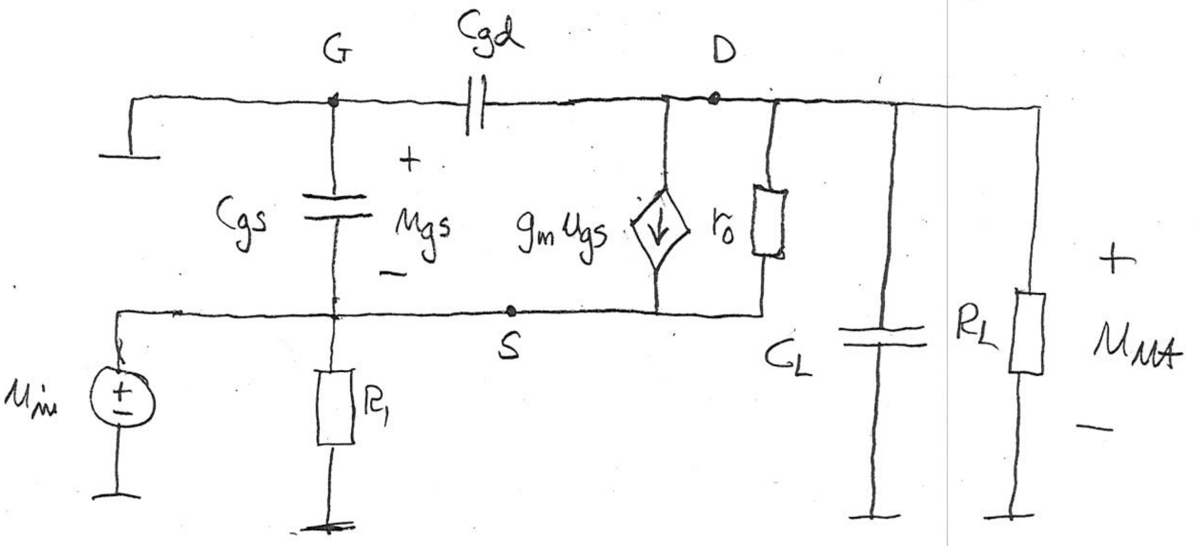
$T(j\omega) = 1 \Rightarrow$

$$\frac{j\omega \cdot \frac{R_4R_1}{R_3} C}{-\omega^2R_1R_2C + 1 + j\omega(R_1+R_2)C} = 1 \Rightarrow$$

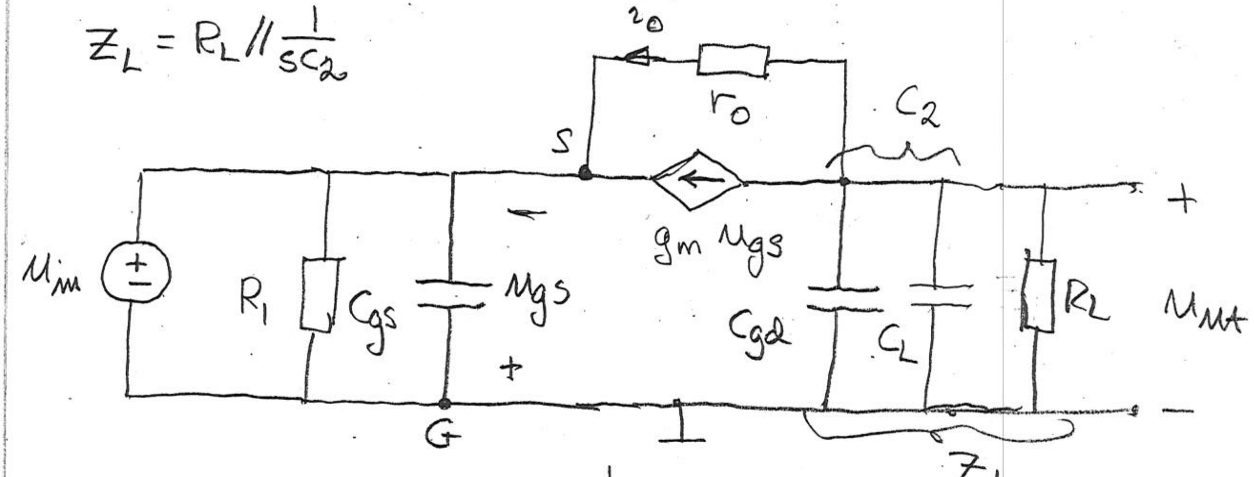
$$\omega = \frac{1}{\sqrt{R_1 \cdot R_2} \cdot C} = \frac{1}{\sqrt{5k \cdot 20k} \cdot 15n} = 6{,}67 \text{ krad/s} = \underline{\underline{1061 \text{ Hz}}}$$

$$\frac{R_4R_1}{R_3} \cdot \cancel{C} = (R_1+R_2)\cancel{C} \Rightarrow R_4 = \frac{R_3(R_1+R_2)}{R_1} = \underline{\underline{5 k\Omega}}$$

6 Småsignalschema



$Z_L = R_L // \frac{1}{sC_2}$



- $Z_L = R_L // \frac{1}{sC_2} = \frac{R_L \cdot \frac{1}{sC_2}}{R_L + \frac{1}{sC_2}} = \frac{R_L}{1 + sR_LC_2}$
- $u_{gs} = -u_{in}$
- $u_{ut} = -Z_L \cdot (i_0 + g_m u_{gs}) = -Z_L i_0 + g_m Z_L \cdot u_{in}$
- $i_0 = \frac{u_{ut} - u_{in}}{r_0}$

$\Rightarrow$

- $u_{ut} = -\frac{Z_L}{r_0}(u_{ut} - u_{in}) + g_m Z_L \cdot u_{in} \Rightarrow$

$r_0 u_{ut} = -Z_L \cdot u_{ut} + Z_L \cdot u_{in} + g_m r_0 Z_L \cdot u_{in} \Rightarrow$

$$u_{ut}(r_0 + Z_L) = Z_L(1+g_m r_0)u_{in} \Rightarrow$$

$$\frac{u_{ut}}{u_{in}} = (1+g_m r_0)\cdot\frac{Z_L}{r_0+Z_L}$$

$$r_0 + Z_L = r_0 + \frac{R_L}{1+sR_LC_2} = \frac{r_0+R_L+sr_0R_LC_2}{1+sR_LC_2} =$$

$$=(r_0+R_L)\cdot\frac{1+s\frac{r_0R_L}{r_0+R_L}\cdot C_2}{1+sR_LC_2} \Rightarrow \left(\frac{r_0R_L}{r_0+R_L} = R_p\right)$$

$$\frac{u_{ut}}{u_{in}} = \frac{1+g_m r_0}{r_0+R_L}\cdot\frac{\frac{R_L}{1+sR_LC_2}}{\frac{1+sR_pC_2}{1+sR_LC_2}} =$$

$$= \frac{(1+g_m r_0)R_L}{r_0+R_L}\cdot\frac{1}{1+sR_pC_2}$$

$r_0 = 20\,k\Omega$, $C_2 = C_L + C_{gd} = 20\cdot10^{-15}\,F$, $R_L = 20\,k\Omega$

$R_p = r_0 /\!/ R_L = \underline{10\,k\Omega}$, $g_m = 1{,}25\,mA/V.$

$$\Rightarrow \quad \omega_{\ddot{o}} = \frac{1}{R_pC_2} = \frac{1}{10\,k\Omega\cdot 20\cdot 10^{-15}\,F} = 5\,Mrad/s \Rightarrow$$

$$\underline{\underline{f_{\ddot{o}} = 796\,kHz}}$$

Tag $s \ll 5\,Mrad/s \Rightarrow$

$$\frac{u_{ut}}{u_{in}} \approx \frac{(1+g_m r_0)\cdot R_L}{r_0+R_L}\cdot\frac{1}{1+0} = \frac{(1+g_m r_0)\cdot R_L}{r_0+R_L} =$$

$$= \underline{\underline{13\,ggr}} = \underline{\underline{22{,}3\,dB}}$$
