Lösningar Elektronik maj 2011

1a. $T_j - T_a = P_f(R_{Thjc} + R_{Thca}) \Rightarrow$

$150°C - 40°C = P_f(2°C/W + 20°C/W) \Rightarrow P_{f_{max}} = \underline{\underline{5W}}$

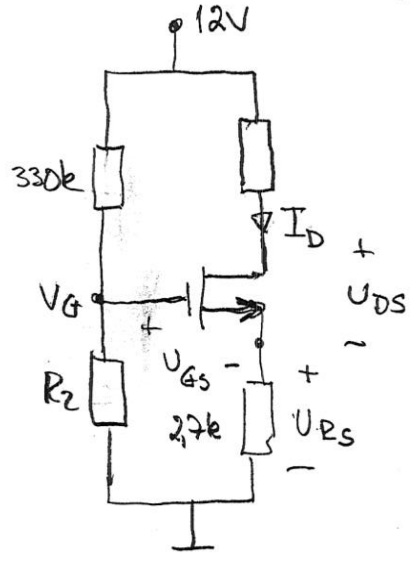
1b. Filteranvändning, kopplingskondensator, avstämning och trimning.

1c. NTC-motstånd: Temperaturmätning
Begränsning av inkopplingsströmstöt.

Varistor: Skydd mot spänningstransienter.

LDR-motstånd: Kretsar där ljusstyrkan styr t.ex. tillslag av belysning.

1d. Antag strömmättnad



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

$I_D = \frac{g_m^2}{2k} = \frac{(4mA/V)^2}{2 \cdot 4mA/V^2} = \underline{2mA}$

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

$U_{GS} = V_t \pm \sqrt{\frac{2I_D}{k}} = 2V \pm 1V = \begin{cases} 3V \\ 1V \end{cases}$

Men $U_{GS} = 1V < V_t$!

Strömmättnad? $U_{DS} = 12V - U_{RS} = 12V - 2{,}7k\Omega \cdot 2mA = 6{,}6V$

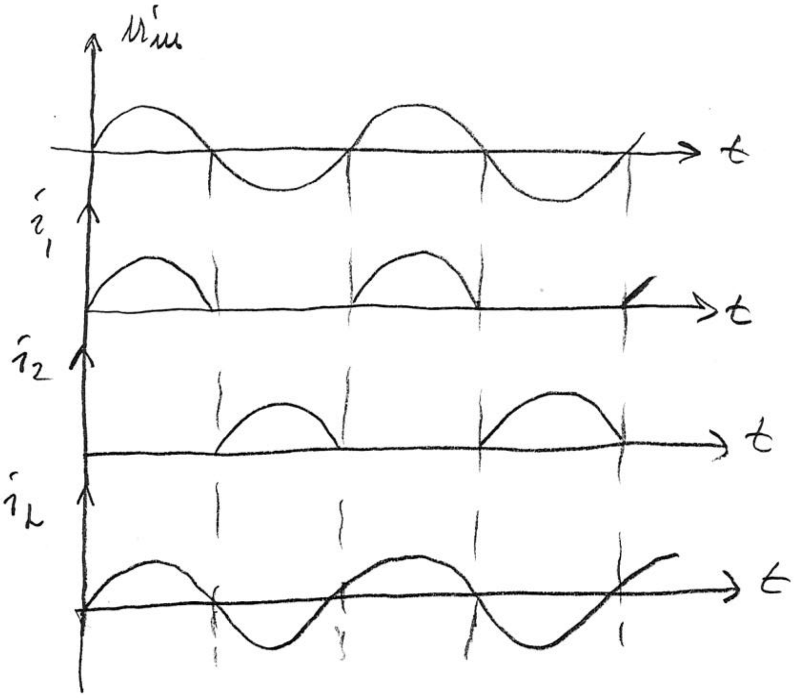
$6{,}6V \geq U_{GS} - V_t = 3V - 2V = 1V$ OK!

$U_{GS} = V_G - U_{RS} = V_G - 5{,}4V \Rightarrow V_G = 3V + 5{,}4V = 8{,}4V$

$V_G = \frac{R_2}{R_2 + 330k\Omega} \cdot 12V \Rightarrow \frac{R_2}{R_2 + 330k\Omega} \cdot 12V = 8{,}4V \Rightarrow$

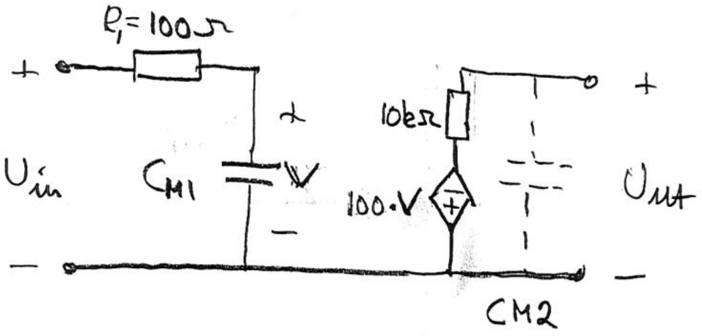
$\underline{\underline{R_2 = 770k\Omega}}$

1e.



Dioderna gör att transistorerna ligger på gränsen att leda. Detta minskar distorsionen i nollgenomgångarna.

1f. Millerapproximation



$C_{M1} =$

$C_{M1} = 200pF + (1-K)\cdot 2pF$. $K = \frac{u_{ut}}{u_{in}} \approx -100 \Rightarrow$

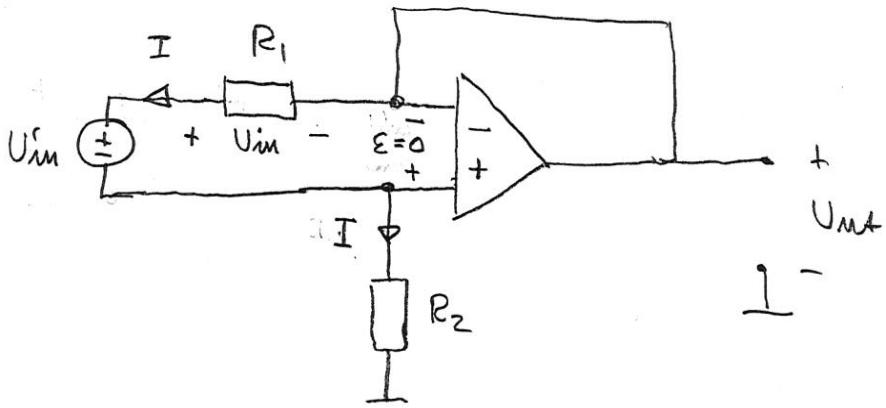
$C_{M1} = 402\,pF$

$C_{M2} = (1 - \frac{1}{K})\cdot 2p$ försummas.

$U_{ut} = -100\cdot V$; $V = \frac{\frac{1}{sC_{M1}}}{R_1 + \frac{1}{sC_{M1}}}\cdot U_{in} = \frac{1}{1+sR_1C_{M1}}\cdot U_{in} \Rightarrow$

$\frac{U_{ut}}{U_{in}} = -\frac{100}{1+sR_1C_{M1}} = -\frac{100}{1+\frac{s}{24{,}9\cdot 10^6}} \Rightarrow \underline{\underline{f_0 = 3{,}96\,MHz}}$

2.] Höga frekvenser, $\frac{1}{\omega C} \approx 0$



Ideal motkopplad OP $\Rightarrow$

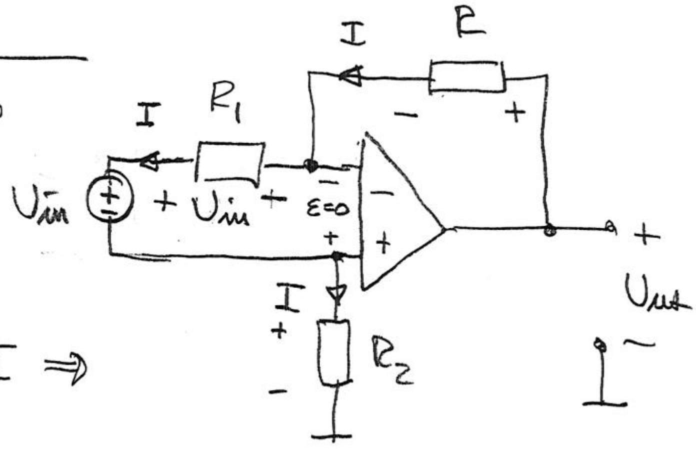
- $\varepsilon = 0$
- inströmmar = 0.

Eftersom $\varepsilon = 0$ ligger U_{in} över R_1 enl. schemat

$$I = \frac{U_{ut}}{R_2} \; ; \quad I = -\frac{U_{in}}{R_1} \Rightarrow \frac{U_{ut}}{R_2} = -\frac{U_{in}}{R_1} \Rightarrow$$

$$\left| \frac{U_{ut}}{U_{in}} \right| = \frac{R_2}{R_1} = 50 \quad (1)$$

Låga frekvenser, $\frac{1}{\omega C} \approx \infty$



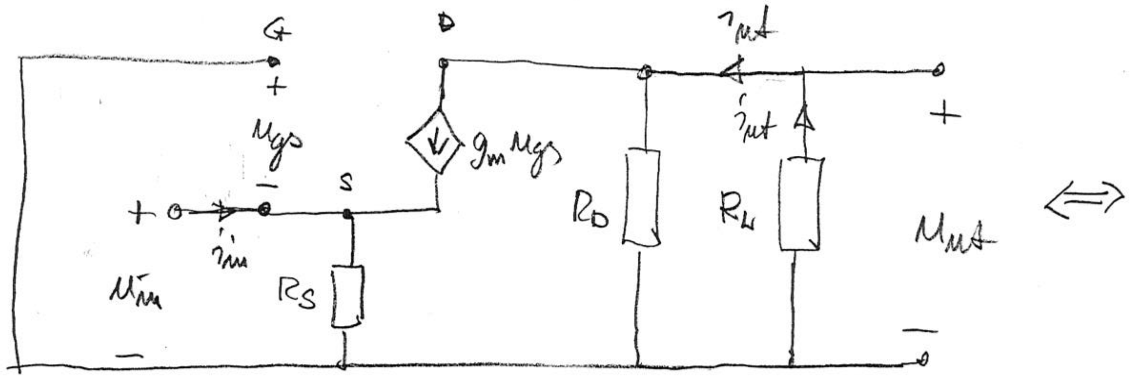
- $I = -\frac{U_{in}}{R_1}$
- $V_+ = V_- \Rightarrow U_{ut} = R \cdot I + R_2 \cdot I \Rightarrow$
- $U_{ut} = -\frac{R + R_2}{R_1} \cdot U_{in} \Rightarrow$

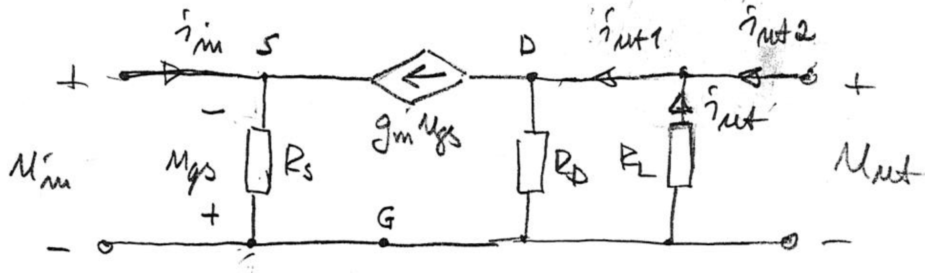
$$\left| \frac{U_{ut}}{U_{in}} \right| = \frac{R + R_2}{R_1} = 100 \Rightarrow \frac{R}{R_1} + \frac{R_2}{R_1} = 100 \quad (2)$$

(1), (2) ger $\frac{R}{R_1} + 50 = 100 \Rightarrow R_1 = \frac{R}{50} = \frac{10k\Omega}{50} = \underline{\underline{200\Omega}}$

(1) ger $\frac{R_2}{200\Omega} = 50 \Rightarrow \underline{\underline{R_2 = 10k\Omega}}$

3.| Småsignalschema (utan r_0)





R_{ut} $\quad R_{ut} = \frac{u_{ut}}{i_{ut1}}\Big|_{u_{in}=0}$. $\quad u_{in}=0 \Rightarrow u_{gs}=0 \Rightarrow$

$g_m u_{gs} = 0$ (avbrott) $\Rightarrow R_{ut} = \frac{u_{ut}}{i_{ut1}} = \underline{\underline{R_D}}$

$\frac{u_{ut}}{u_{in}}$ $\quad \left.\begin{aligned} u_{ut} &= -g_m u_{gs}\cdot R_L // R_D \\ u_{gs} &= -u_{in} \end{aligned}\right\} \Rightarrow \frac{u_{ut}}{u_{in}} = \underline{\underline{g_m(R_L // R_D)}}$

R_{in} $\quad R_{in} = \frac{u_{in}}{i_{in}}\Big|_{i_{ut2}=0} \quad u_{in} = (i_{in} + g_m u_{gs})\cdot R_S =$

$= (i_{in} - g_m u_{in})\cdot R_S \Rightarrow u_{in}(1+g_m R_S) = R_S \cdot i_{in} \Rightarrow$

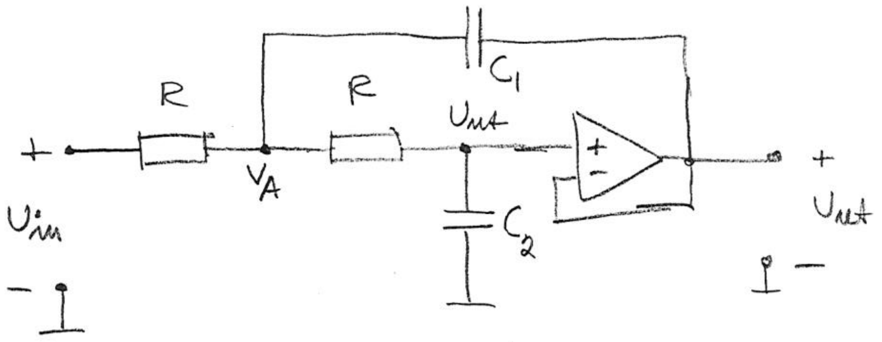
$R_{in} = \frac{u_{in}}{i_{in}} = \underline{\underline{\frac{R_S}{1+g_m R_S}}}$

$\frac{i_{ut}}{i_{in}}$ $\quad i_{ut} = -\frac{u_{ut}}{R_L}$; $\frac{u_{in}}{R_S} = i_{in} + g_m u_{gs} = i_{in} - g_m u_{in} \Rightarrow$

$i_{in} = \left(\frac{1}{R_S} + g_m\right)\cdot u_{in} \Rightarrow \frac{i_{ut}}{i_{in}} = -\frac{\frac{1}{R_L}}{\frac{1}{R_S}+g_m}\cdot\frac{u_{ut}}{u_{in}} = -\frac{\frac{1}{R_L}}{\frac{1}{R_S}+g_m}\cdot g_m(R_L // R_D) =$

$= \underline{\underline{\frac{g_m R_S}{1+g_m R_S}\cdot\frac{R_D}{R_D+R_L}}}$

4.



Nodanalys:

- $\frac{V_A - U_{in}}{R} + \frac{V_A - U_{ut}}{R} + sC_1(V_A - U_{ut}) = 0 \Rightarrow$

$(2 + sRC_1)V_A - (1 + sRC_1)\cdot U_{ut} = U_{in} \quad (1)$

- $\frac{U_{ut} - V_A}{R} + sC_2 \cdot U_{ut} = 0 \Rightarrow V_A = (1 + sRC_2)U_{ut} \quad (2)$

(1),(2) ger $(2 + sRC_1)(1 + sRC_2)\cdot U_{ut} - (1 + sRC_1)\cdot U_{ut} = U_{in} \Rightarrow$

$$\frac{U_{ut}}{U_{in}} = \frac{1}{2 + 2sRC_2 + sRC_1 + s^2R^2C_1C_2 - 1 - sRC_1} = \frac{1}{s^2R^2C_1C_2 + s\cdot 2RC_2 + 1} =$$

$$= \frac{\frac{1}{R^2C_1C_2}}{s^2 + \frac{2}{RC_1}\cdot s + \frac{1}{R^2C_1C_2}}.$$ Kritiskt dämpad $\Leftrightarrow$

gränsfallet mellan reella och komplexa poler:

$$s^2 + \frac{2}{RC_1}s + \frac{1}{R^2C_1C_2} = 0 \Rightarrow s = -\frac{1}{RC_1} \pm \underbrace{\sqrt{\frac{1}{R^2C_1^2} - \frac{1}{R^2C_1C_2}}}_{=0}$$

$$\Rightarrow \frac{1}{R^2C_1^2} = \frac{1}{R^2C_1C_2} \Leftrightarrow \underline{C_1 = C_2 = 100\,\mu F}$$

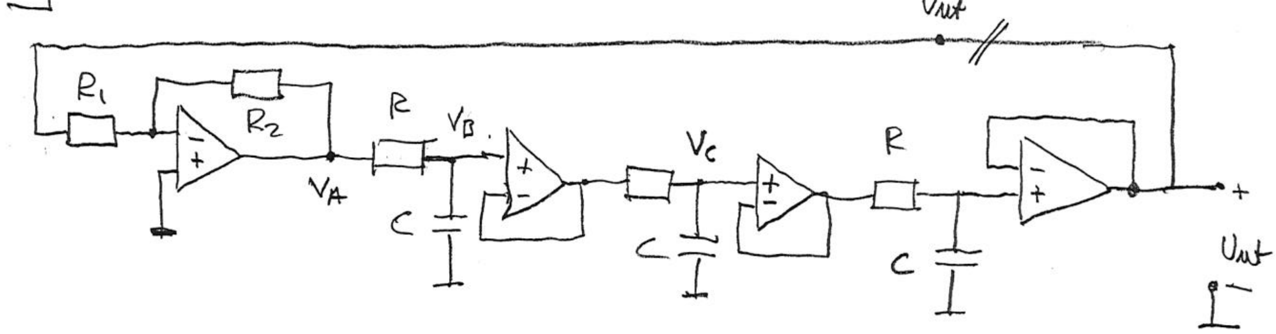
$$\Rightarrow \frac{U_{ut}}{U_{in}} = \frac{\frac{1}{R^2C_1^2}}{\left(s + \frac{1}{RC_1}\right)^2} \quad (LP)$$ Fmax inträffar

då $s = 0 \Rightarrow \underline{F_{max}} = \frac{\frac{1}{R^2C_1^2}}{\left(0 + \frac{1}{RC_1}\right)^2} = \underline{1}$

$$\omega_{\ddot{o}TOT} = \sqrt{2^{1/2} - 1}\cdot\omega_{\ddot{o}} = \sqrt{2^{1/2} - 1}\cdot\frac{1}{RC_1} = 6{,}44\ \text{krad/s} \Rightarrow$$

$\underline{f_{\ddot{o}TOT} = 1{,}02\ \text{kHz}}$

5.



$V_A = -\frac{R_2}{R_1} \cdot U'_{ut}$; $R = 10\,k\Omega$; $R_1 = 12\,k\Omega$; $C = 10\,nF$

$V_B = \frac{\frac{1}{sC}}{\frac{1}{sC}+R} \cdot V_A = \frac{1}{1+sRC} \cdot V_A$. På samma sätt

$V_C = \frac{1}{1+sRC} \cdot V_B$; $U_{ut} = \frac{1}{1+sRC} \cdot V_C \Rightarrow$

$U_{ut} = -\frac{R_2}{R_1} \cdot \frac{1}{(1+sRC)^3} \cdot U'_{ut} \Rightarrow T(s) = \frac{U_{ut}}{U'_{ut}} = -\frac{R_2}{R_1} \cdot \frac{1}{(1+sRC)^3}$

$\Rightarrow T(j\omega) = -\frac{R_2}{R_1} \cdot \frac{1}{(1+j\omega RC)^3} = -\frac{R_2}{R_1} \cdot \frac{1}{1-3\omega^2R^2C^2+j(3\omega RC - \omega^3R^3C^3)}$

$T(j\omega) = 1$ kräver $\text{Im}\,T(j\omega) = 0$, så att

$3\omega RC - \omega^3R^3C^3 = 0 \Rightarrow \omega RC(3-\omega^2R^2C^2) = 0 \Rightarrow$

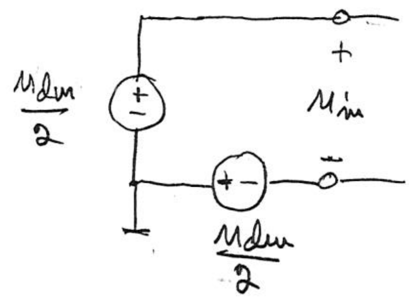
$\omega = \frac{\sqrt{3}}{RC} = \frac{\sqrt{3}}{10k\Omega \cdot 10nF} = 17{,}32$ krad/s $\Rightarrow f = \underline{\underline{2{,}76\,kHz}}$

$T(j\omega) = 1$ ger nu att $-\frac{R_2}{R_1} \cdot \frac{1}{1-3\cdot\frac{3}{R^2C^2}\cdot R^2C^2} = 1 \Rightarrow$

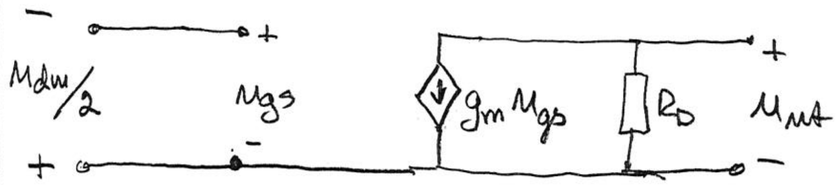
$-\frac{R_2}{R_1} \cdot \frac{1}{1-9} = 1 \Rightarrow R_2 = 8R_1 = \underline{\underline{96\,k\Omega}}$

6.1 DM-signaler

Betrakta högra transistorn

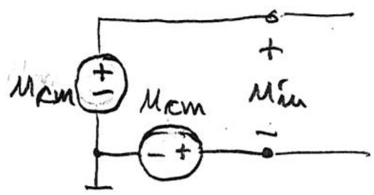


Småsignalschema:

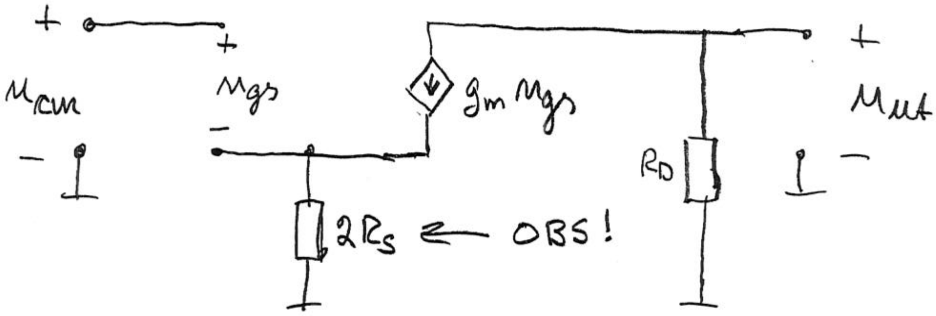


$$A_{DM} = \frac{u_{ut}}{u_{dm}} = \frac{-g_m R_D u_{gs}}{-2u_{gs}} = \frac{g_m R_D}{2} = \frac{6\,mA/V \cdot 8{,}2\,k\Omega}{2} = \underline{24{,}6\text{ ggr}}$$

CM-signaler



Småsignalschema (t.ex. vänstra transistorn)



$$\left.\begin{aligned} u_{ut} &= -g_m u_{gs} \cdot R_D \\ u_{cm} &= u_{gs} + g_m u_{gs} \cdot 2R_S \end{aligned}\right\} \Rightarrow A_{CM} = \frac{u_{ut}}{u_{cm}} = \frac{-g_m R_D \cdot u_{gs}}{(1+2g_m R_S)\cdot u_{gs}} =$$

$$= -\frac{g_m R_D}{1+2g_m R_S} = -\frac{6\,mA/V \cdot 8{,}2\,k\Omega}{1+2\cdot 6\,mA/V \cdot 1{,}2\,k\Omega} = \underline{-3{,}19\text{ ggr}}$$

$$CMRR = \left|\frac{A_{DM}}{A_{CM}}\right| = \frac{24{,}6}{3{,}19} = 7{,}70\text{ ggr} = \underline{\underline{17{,}7\,dB}}$$
