Svar till tenta Elektronik gk 8/1-04

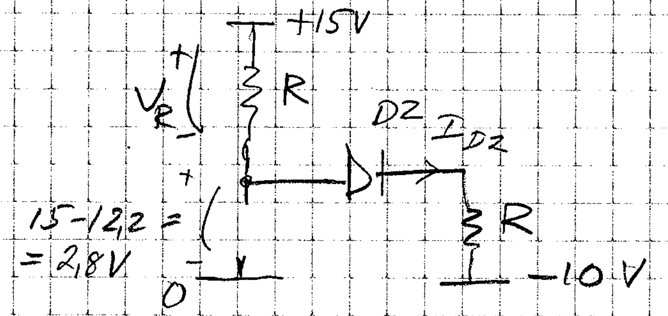
A1. Minsta R_1 blir $\frac{10V}{20mA} = R_1 + R_2 =$

$= R_1 + 400\Omega = 500\Omega \Rightarrow R_1 = 100\Omega$

$A_V = \frac{R_1+R_2}{R_1} = \frac{100+400}{100} = \underline{5\text{ ggr}}$

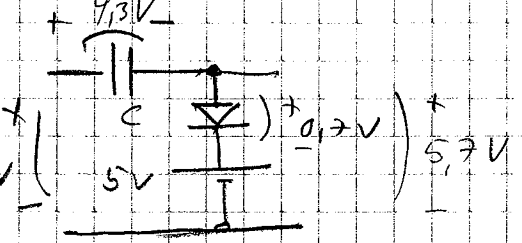
A2. $I_{D2} = \frac{25V-0{,}6V}{2R} = \frac{24{,}4V}{20k\Omega} = \underline{1{,}22mA}$

$V_R = R \cdot I_{D2} = 10 \cdot 1{,}22 = 12{,}2V$



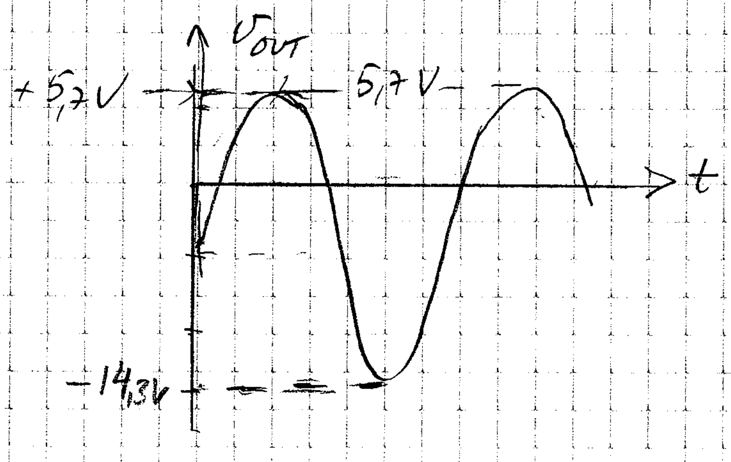
$I_{D1} = 0$ ty dioden ligger backspänd.

A3. $V_{IN} = +10V \Rightarrow$



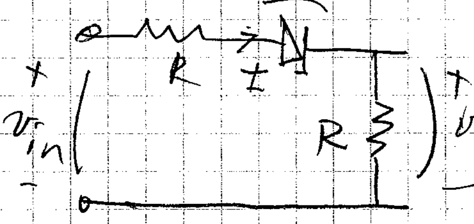
Kondensatorspän $\approx 4{,}3V$ [hinner inte laddas ur då $V_{IN} < +10V$].

$\therefore\ v_{OUT} = v_{IN} - 4{,}3V$.



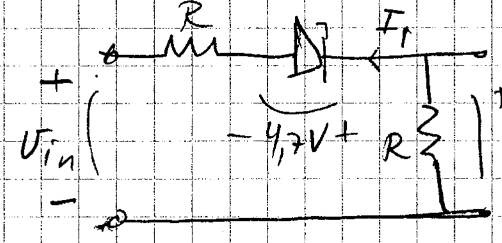
A4/ Koppla ett dekadmotstånd på utgången. Då utspänning sjunkit till hälften är $R_{Dekad} = R_{out}$. ∴ R_{out} kan avläsas på dekadmotståndet.

A5/ $V_{in} > 0{,}7V$



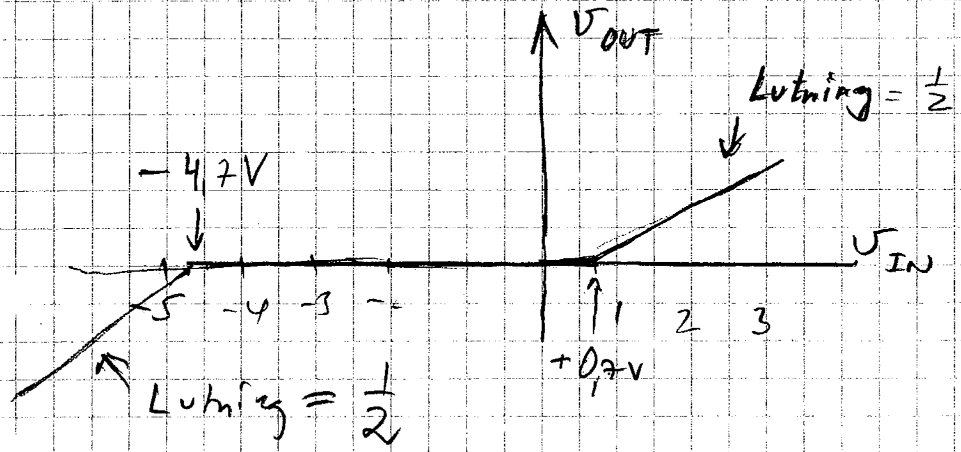
$v_{out} = I \cdot R = \dfrac{v_{in} - 0{,}7V}{2R} \cdot R = \dfrac{v_{in}}{2} - 0{,}35V$

$V_{in} < -4{,}7V$

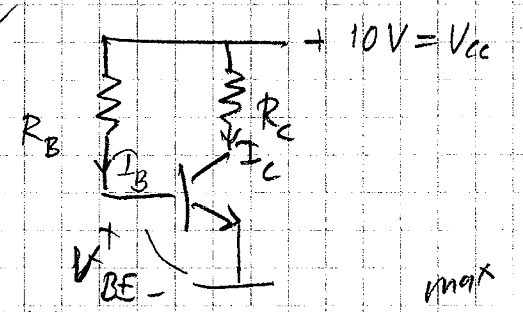


$v_{out} = -I_1 \cdot R = -\dfrac{v_{in} - 4{,}7V}{2R} \cdot R$

$= -\dfrac{v_{in}}{2} + \dfrac{4{,}7}{2} = -\dfrac{v_{in}}{2} + 2{,}35V$



A6/



$$\begin{cases} V_{cc} = I_B \cdot R_B + V_{BE} \\ \text{där } I_B = \dfrac{I_C}{\beta} \end{cases}$$

$V_{cc} = I_C \cdot \dfrac{R_B}{\beta} + V_{BE}$

$10V = I_C \cdot \dfrac{100k\Omega}{200} + V_{BE}$

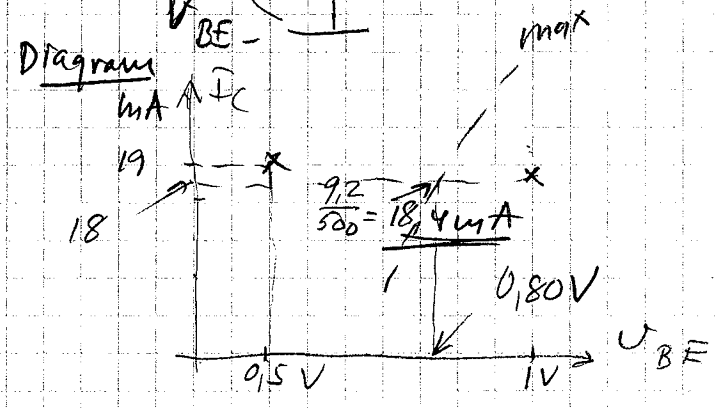
$\Rightarrow 10 = I_C \cdot 500 + V_{BE}$

$V_{BE} = 1V \Rightarrow I_C = \dfrac{9}{500} = 18\,mA$

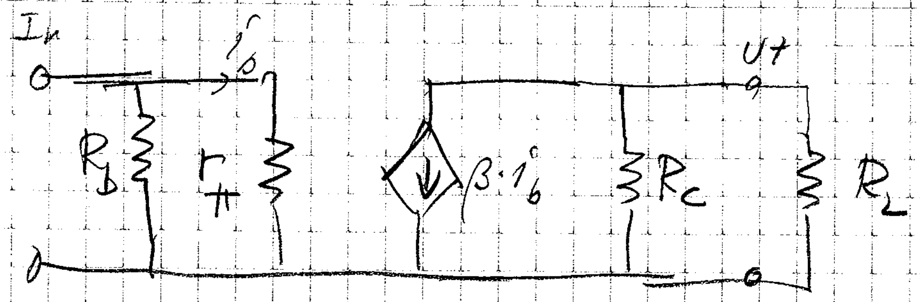
$V_{BE} = 0{,}5V \Rightarrow I_C = \dfrac{9{,}5}{500} = 19\,mA$

Kurvan $\Rightarrow V_{BEQ} = 0{,}80V$ $I_{CQ} = \underline{18{,}4\,mA}$

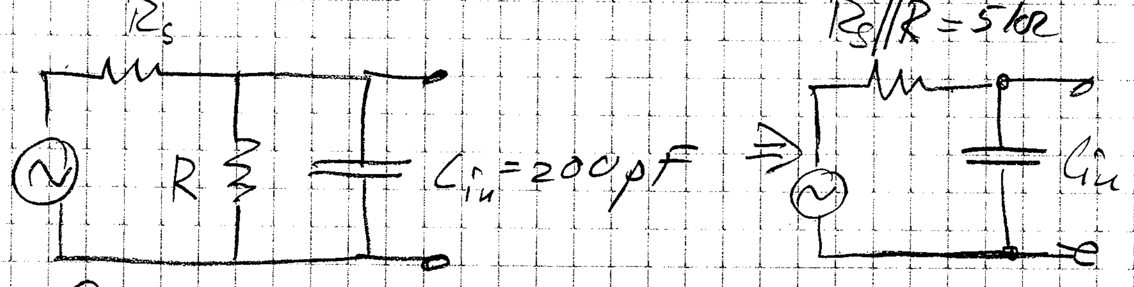
Diagram



A7/



A8/



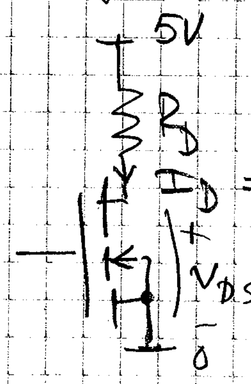
$$f_H = \frac{1}{2\pi C_{in} \cdot (R_S \| R)} = \frac{1}{2\pi \cdot 200 \cdot 10^{-12} \cdot 5 \cdot 10^3} =$$

$$= \underline{159 kHz}$$

A9/

Triodregion: $I_D = K\left(2(V_{GS} - V_{to}) V_{DS} - V_{DS}^2\right)$

$$= 50\left(2 \cdot (5-2) \cdot V_{DS} - V_{DS}^2\right) \mu A$$



$$I_D = \frac{5V - V_{DS}}{R_D} = \frac{5V - V_{DS}}{20k\Omega}$$

$$\therefore I_D = \frac{5V - V_{DS}}{20k\Omega} = 50\mu A/V^2 \left(6 V_{DS} - V_{DS}^2\right)$$

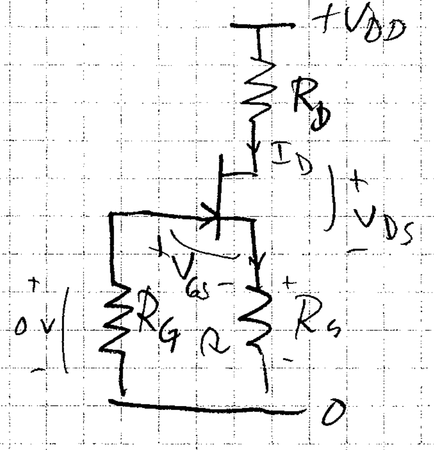
$$\Rightarrow 5 - V_{DS} = 6V_{DS} - V_{DS}^2$$

$$\Rightarrow V_{DS}^2 - 7V_{DS} + 5 = 0 \Rightarrow V_{DS} = 3{,}5 \pm \sqrt{3{,}5^2 - 5}$$

$$= 3{,}5 \overset{(-)}{\pm} 2{,}69 = \underline{0{,}81\ V}$$

A10/ $X = \overline{A \cdot B}$ (NAND-grind)

B1/



$\circlearrowleft \quad V_{GS} + I_D \cdot R_S = 0$ — (1)

$\downarrow \quad V_{DD} = I_D \cdot R_D + V_{DS} + I_D \cdot R_S$ — (2)

$I_D = K \cdot (V_{GS} - V_{to})^2$ — (3)

där $K = \frac{I_{DSS}}{V_{to}^2} = \frac{12}{16}\ mA/V^2$

$(3) \rightarrow (1) \Rightarrow V_{GS} + K(V_{GS} - V_{to})^2 \cdot R_S = 0$

$\Rightarrow V_{GS} + \frac{12mA}{(-4V)^2}(V_{GS} + 4V)^2 \cdot 0{,}28k\Omega = 0$

$\Rightarrow V_{GS} + 0{,}21(V_{GS} + 4V)^2 = 0$

$\Rightarrow 4{,}76 \cdot V_{GS} + V_{GS}^2 + 8 \cdot V_{GS} + 16 = 0$

$\Rightarrow V_{GS}^2 + 12{,}76 V_{GS} + 16 = 0 \Rightarrow V_{GS} = -6{,}38 \pm \underbrace{\sqrt{40{,}7 - 16}}_{4{,}97}$

$V_{GS} = -1{,}4084V$

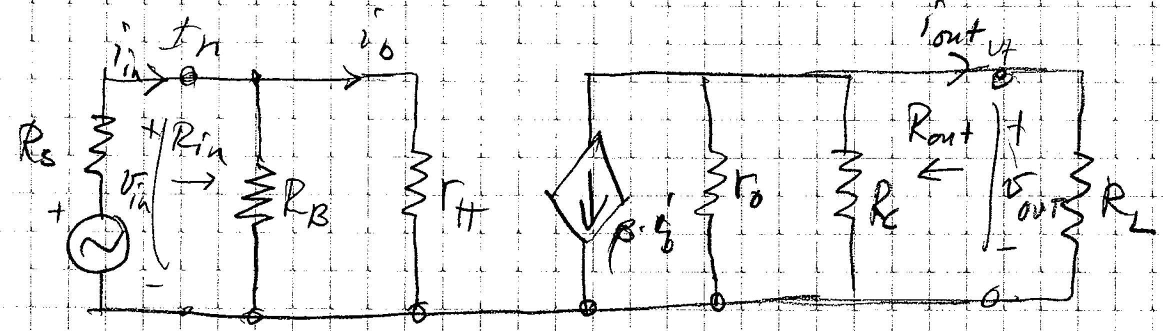
$(1) \Rightarrow -1{,}4V + I_D \cdot 0{,}28k\Omega = 0 \Rightarrow$

$\Rightarrow I_D = \frac{1{,}4}{0{,}28} = 5{,}03\ mA \approx \underline{5{,}0\ mA} = I_{DQ}$

$(2) \Rightarrow V_{DS} = V_{DD} - I_D(R_D + R_S) = 18V - 5mA(2 + 0{,}28)k\Omega$

$= 6{,}53 \approx \underline{6{,}5V}$

B2/ Ekv. signalschema



$$R_{in} = R_B // r_\pi = 1{,}5\,M\Omega // 2{,}6\,k\Omega \approx 2{,}595 \approx \underline{2{,}6\,k\Omega}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta}{\frac{I_{CQ}}{V_T}} = \frac{200 \cdot 0{,}026}{2\,mA} = 2{,}6\,k\Omega$$

$$R_{out} = r_o // R_C = 50 // 5 = 4{,}545 \approx \underline{4{,}5\,k\Omega}$$

$$A_V = \frac{v_{out}}{v_{in}} = -g_m \cdot (r_o // R_C // R_L)$$

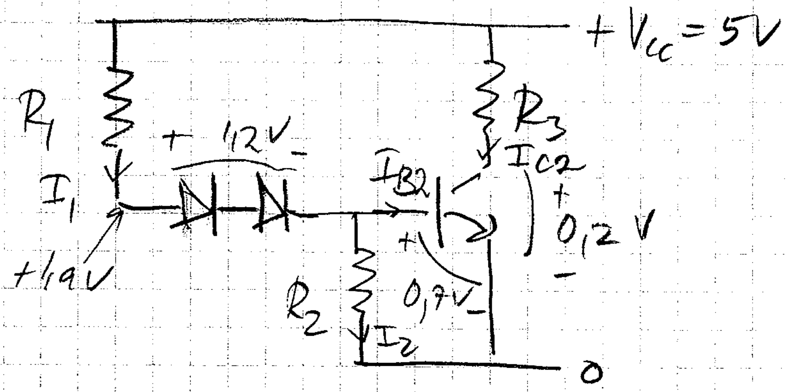
$$g_m = \frac{I_{CQ}}{V_T} = \frac{2}{0{,}026} = 76{,}92\,mA/V$$

$$A_V = \frac{v_{out}}{v_{in}} = -76{,}92\,mA/V \cdot \underbrace{(50\,k\Omega // 5\,k\Omega // 10\,k\Omega)}_{3{,}125\,k\Omega} =$$
$$= \underline{-240\ ggr}$$

$$A_i = \frac{i_{out}}{i_{in}} = \frac{\frac{v_{out}}{R_L}}{\frac{v_{in}}{R_{in}}} = \frac{v_{out}}{v_{in}} \cdot \frac{R_{in}}{R_L} =$$

$$= -240 \cdot \frac{2{,}6}{10} = \underline{-62{,}5\ ggr}$$

B3/



Sämsta fallet då $\beta = 100$ (min-värde).

$$I_{C2} = \frac{5V - 0{,}2V}{R_3} = \frac{4{,}8}{50} = 96 \text{ mA}$$

$$\Rightarrow I_{B2} = \frac{I_{C2}}{\beta_{min}} = \frac{96}{100} = 0{,}96 \text{ mA}$$

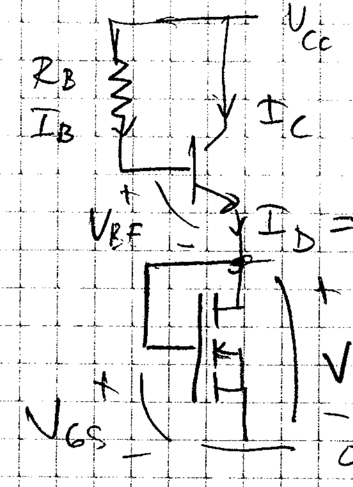
$$I_2 = \frac{U_{BE}}{R_2} = \frac{0{,}7V}{500\Omega} = 1{,}4 \text{ mA}$$

$$I_1 = \frac{5V - 1{,}9V}{R_1} = \frac{3{,}1V}{R_1} = I_2 + I_{B2} = (0{,}96 + 1{,}4) \text{ mA}$$

$$= 2{,}36 \text{ mA} \quad \Rightarrow \quad R_1 = \frac{3{,}1V}{2{,}36} = \underline{\underline{1{,}31 \text{ k}\Omega}}$$

B4/

$$K = \frac{1}{2} KP \frac{W}{L} = \frac{1}{2} \cdot 50\,\mu A/V^2 \frac{100\,\mu m}{10\,\mu m} = 0{,}25\, mA/V^2$$



$I_D = I_C + I_B = (\beta+1) \cdot I_B$

$V_{DS} = V_{GS}$

MOS-transistorn är konstant strömgenerator.

$$I_D = K(V_{GS} - V_{t0})^2 = I_B(\beta+1)$$

$$I_B = \frac{V_{CC} - V_{BE} - V_{DS}}{R_B} = \frac{10 - 0{,}7 - V_{DS}}{132\,k\Omega}$$

$$I_D = 0{,}25\,mA/V^2 (V_{DS} - 2V)^2 = \frac{9{,}3 - V_{DS}}{132\,k\Omega} \cdot 161$$

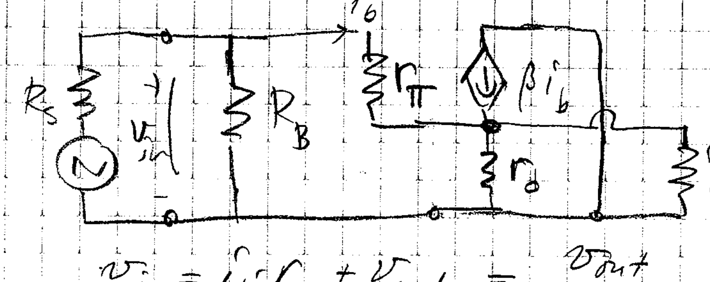
$$\Rightarrow (V_{DS} - 2)^2 = \left(\frac{9{,}3}{33} - \frac{V_{DS}}{33}\right) 161 =$$

$$\Rightarrow V_{DS}^2 - 4V_{DS} + 4 - 45{,}37 + 4{,}879 V_{DS} = 0$$

$$V_{DS}^2 + 0{,}879 V_{DS} - 41{,}37 = 0$$

$$V_{DS} = -0{,}439 (\pm) \underbrace{\sqrt{0{,}439^2 + 41{,}37}}_{6{,}447} = 6{,}0\ V$$

$$I_{DQ} = 4{,}0\ mA \approx I_{CQ}$$



$v_{out} = i_b(1+\beta) \cdot r_0 // R_L$

$$v_{in} = i_b \cdot r_\pi + v_{out} = \frac{v_{out}}{(1+\beta)\, r_0 // R_L} \cdot r_\pi + v_{out}$$

$$\Rightarrow v_{in} = v_{out}\left(1+\frac{r_\pi}{(1+\beta)\,r_d \| R_L}\right) =$$

$$= v_{out} \cdot \frac{(1+\beta)(r_d \| R_L) + r_\pi}{(1+\beta)(r_d \| R_L)}$$

$$\frac{v_{out}}{v_{in}} = \frac{(1+\beta)\cdot(r_d \| R_L)}{r_\pi + (1+\beta)\cdot(r_d \| R_L)} = \frac{161 \cdot 20k\Omega \| 100\Omega}{1k\Omega + 161 \cdot (20k\Omega \| 100\Omega)}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta}{\frac{I_{CQ}}{V_T}} = \frac{160}{\frac{4mA}{0{,}026V}} = 1{,}04\ k\Omega$$

$$\Rightarrow A_v = \underline{0{,}941}$$

$$\left(A_v = \frac{(1+\beta)\cdot R_L'}{r_\pi + (1+\beta)\cdot R_L'}\right.$$

enl. formelsaml.)

$$Z_0 = R_{out} =$$

$$= \frac{1}{(1+\beta)/(R_s' + r_\pi) + \frac{1}{R_E}} = (\text{där } R_s' = R_S \| R_B)$$

$$= \frac{1}{\frac{161}{1{,}04k\Omega + \frac{20 \cdot 132}{20+132}k\Omega} + \frac{1}{20k\Omega}} = 113{,}7 \approx \underline{114\ \Omega}$$

$$A_p = A_v \cdot A_i = \frac{v_{out}}{v_{in}} \cdot \frac{\frac{v_{out}}{R_L}}{\frac{v_{in}}{R_{in}}} = \frac{R_{in}}{R_L} \cdot A_v^2 =$$

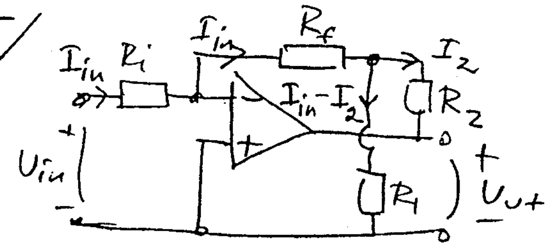
$$= \frac{15{,}1k\Omega}{0{,}1k\Omega} \cdot 0{,}941^2 = \underline{\underline{133\ ggr}}$$

$$R_{in} = R_B \| (r_\pi + (1+\beta)\cdot R_L')$$ enl. formelsaml.

$$\Rightarrow R_{in} = 132k\Omega \| (1{,}04 + (1+160)\cdot 99{,}5\Omega) = 132k\Omega \| 17k\Omega = 15{,}1k\Omega$$

$$R_L' = r_d \| R_L = 20k\Omega \| 100\Omega = 99{,}5\ \Omega$$

B5/



Ohms lag

$$I_{in} = \frac{U_{in}}{R_i} \quad \text{---} (1)$$

Kirch. sp. lag

$$U_{ut} + I_2 R_2 - R_1(I_{in} - I_2) = 0 \text{-}(2)$$

$$U_{ut} + I_2 R_2 + R_f I_{in} = 0 \text{-}(3)$$

(3) ger

$$I_2 = -\frac{1}{R_2}\left(U_{ut} + R_f \frac{U_{in}}{R_i}\right)$$

Insättes i (2)

$$U_{ut} + (R_1 + R_2)\cdot\frac{1}{-R_2}\left(U_{ut} + R_f\frac{U_{in}}{R_i}\right) - R_1\cdot\frac{U_{in}}{R_i} = 0$$

$$\Rightarrow U_{ut}\left(\cancel{1} - \frac{R_1}{R_2} - \cancel{\frac{R_2}{R_2}}\right) = U_{in}\left(\frac{R_1}{R_i} + \frac{R_1 + R_2}{R_2}\cdot\frac{R_f}{R_i}\right)$$

$$\Rightarrow A_v = \frac{U_{ut}}{U_{in}} = -\frac{R_2}{R_1}\left(\frac{R_1}{R_i} + \frac{R_1}{R_2}\cdot\frac{R_f}{R_i} + \frac{R_f}{R_i}\right) =$$

$$= -\underline{\left(\frac{R_2}{R_i} + \frac{R_f}{R_i} + \frac{R_2}{R_1}\cdot\frac{R_f}{R_i}\right)}$$