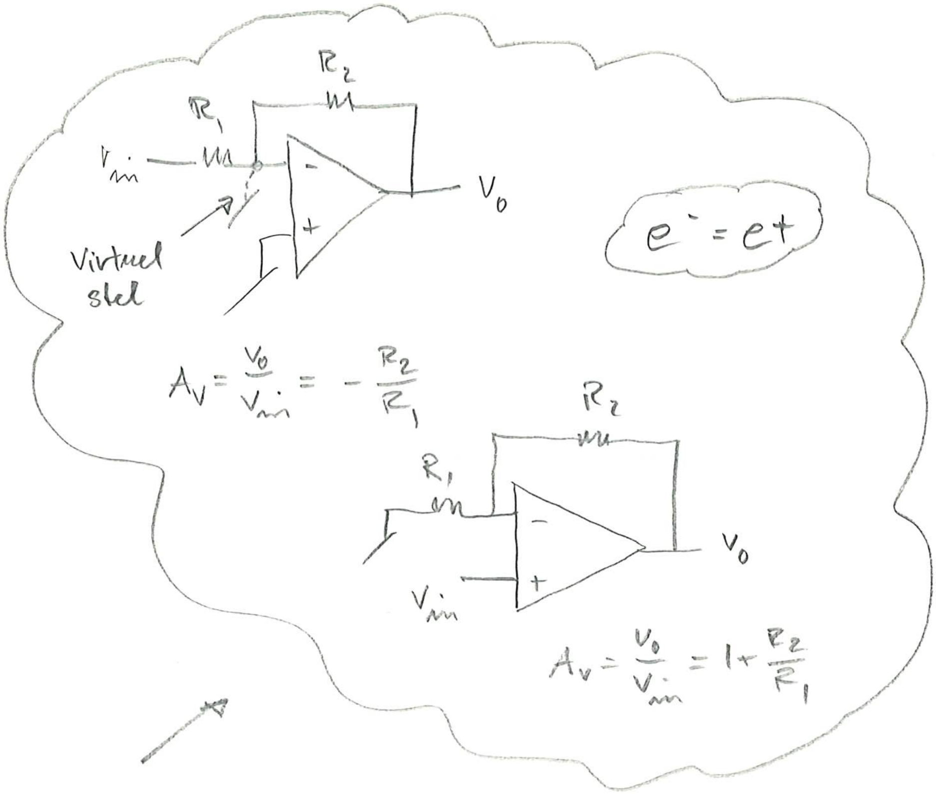
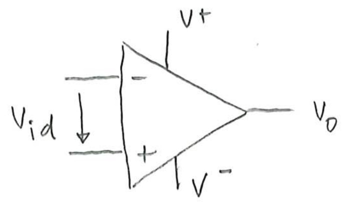
Ideel Performance



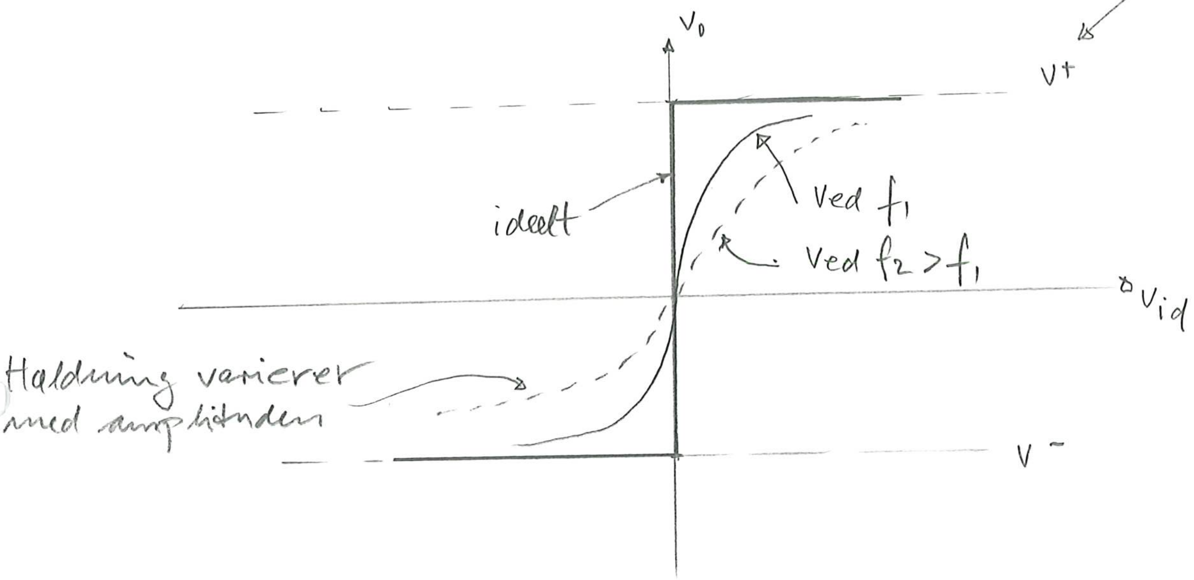


$$V_o = A_{OL} \cdot V_{id}$$

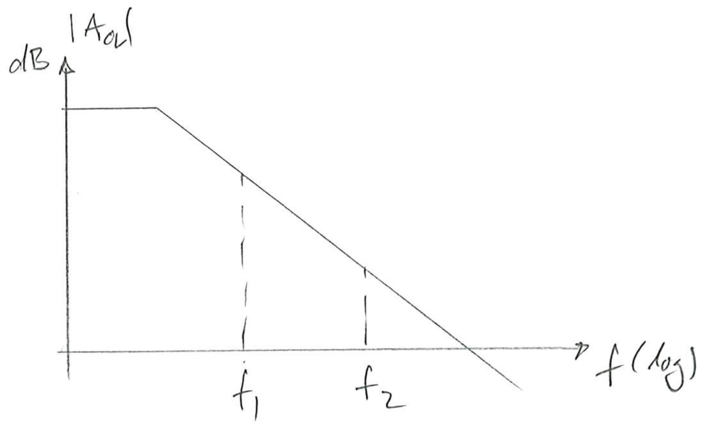
$$\frac{dV_o}{dV_{id}} = A_{OL}$$

Hældnings-koeff.

Alt dette er betinget af, at $A_{OL} \to \infty$

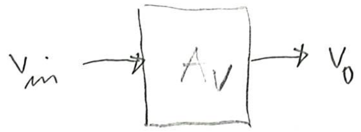


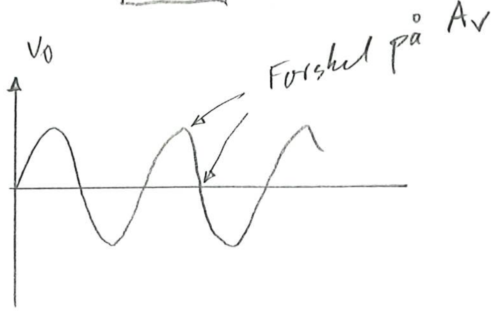
Datablad

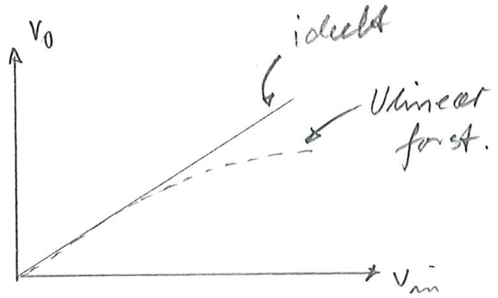


Hvis forstærkning varierer med amplitude $\Rightarrow$

Forvrængning







Forstærker med negativ feedback (se note)

$$V_0 = A_{OL} \cdot V_{id} = A_{OL} \cdot (\alpha \cdot V_{in} - \beta \cdot V_0) \Rightarrow$$

$$V_0 (1 + \beta A_{OL}) = A_{OL} \cdot \alpha \cdot V_{in} \Rightarrow \quad V_0 = \frac{\alpha \cdot A_{OL}}{1 + \beta A_{OL}} \cdot V_{in} \Rightarrow$$

$$A_{CL} = \frac{V_0}{V_{in}} = \frac{\alpha \cdot A_{OL}}{1 + \beta A_{OL}} = \frac{\alpha}{\beta} \cdot \frac{A_{OL}}{\frac{1}{\beta} + A_{OL}} = \frac{\alpha}{\beta} \cdot \frac{1}{1 + \frac{1}{\beta A_{OL}}}$$

$$= \frac{\alpha}{\beta} \cdot K_f$$

Fejlfaktor K_f

NB! Ideel OpAmp

$\downarrow$

$A_{OL} \to \infty$

$\downarrow$

$K_f = 1$

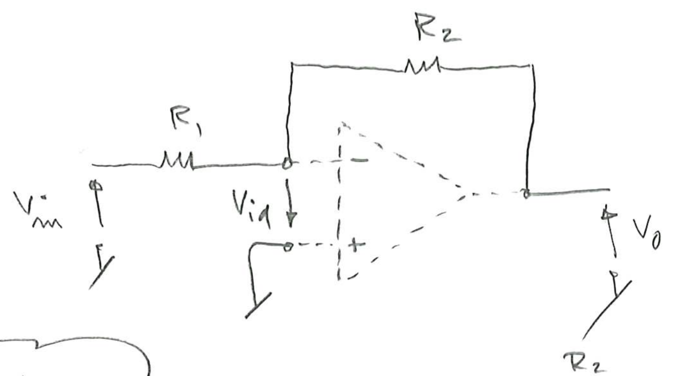
Hvad er α og β?

$$V_{id} = \alpha \cdot V_{in} - \beta \cdot V_0$$

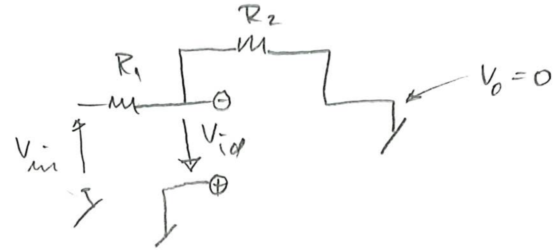
$$\alpha = \left. \frac{V_{id}}{V_{in}} \right|_{V_0 = 0} \qquad \beta = - \left. \frac{V_{id}}{V_0} \right|_{V_{in} = 0}$$

$\downarrow$ Eksempel

Inverterende kobling

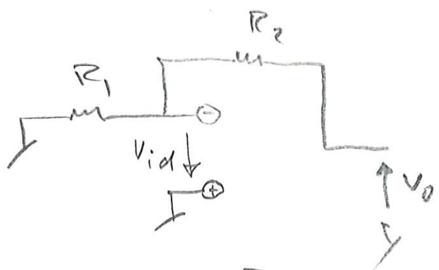


$$\alpha = \left.\frac{V_{id}}{V_{in}}\right|_{V_o=0}$$



$$V_{id} = -V_{in}\,\frac{R_2}{R_1+R_2} \Rightarrow \underline{\alpha = \frac{V_{id}}{V_{in}} = -\frac{R_2}{R_1+R_2}}$$

$$\beta = -\left.\frac{V_{id}}{V_o}\right|_{V_{in}=0}$$

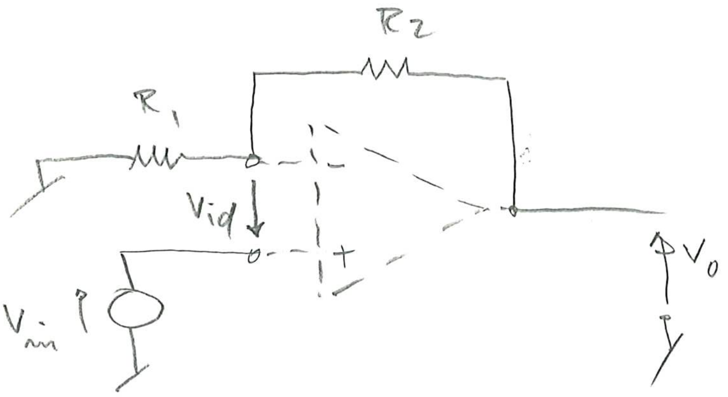


$$V_{id} = -\frac{R_1}{R_1+R_2}\cdot V_o \Rightarrow \underline{\beta = -\frac{V_{id}}{V_o} = \frac{R_1}{R_1+R_2}}$$

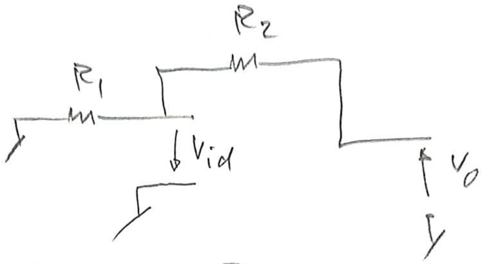
$$\frac{\alpha}{\beta} = A_{CL\,ideal} = -\frac{R_2}{\cancel{R_1+R_2}}\cdot\frac{\cancel{R_1+R_2}}{R_1} = \underline{\underline{-\frac{R_2}{R_1}}}$$

Ideal A_{CL}; dvs. for $A_{OL} \to \infty \Rightarrow k_f = 1$

Ikke-inverterende kobling

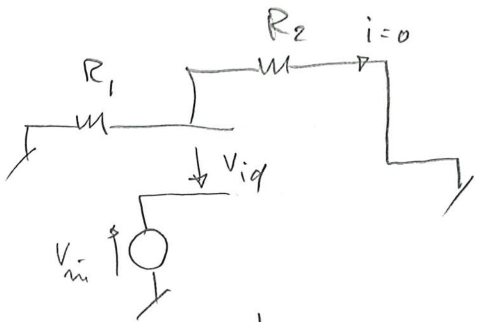


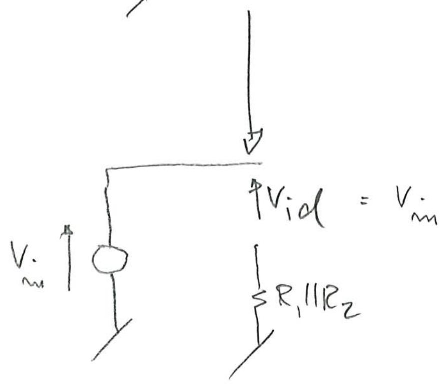
$$\beta = -\left.\frac{V_{id}}{V_o}\right|_{V_{in}=0}$$



$$V_{id} = -V_o \frac{R_1}{R_1+R_2} \Rightarrow \beta = -\frac{V_{id}}{V_o} = \frac{R_1}{R_1+R_2}$$

$$\alpha = \left.\frac{V_{id}}{V_{in}}\right|_{V_o=0}$$

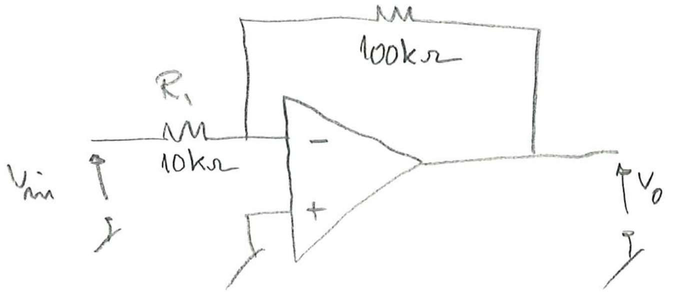




$$\alpha = \frac{V_{id}}{V_{in}} = 1$$

$$\frac{\alpha}{\beta} = 1 \cdot \frac{R_1+R_2}{R_1} = \underline{\underline{\frac{R_1+R_2}{R_1} = 1 + \frac{R_2}{R_1}}}$$

Sp. 3 fra forberedelsen



$$A_{OL} = 10^6$$

$$A_{CL} = \frac{\alpha}{\beta} \cdot K_f$$

$$\frac{\alpha}{\beta} = -\frac{R_2}{R_1} \quad (\text{idealt})$$

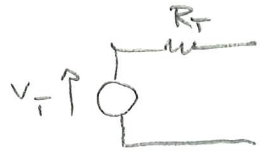
Fejl ligger i K_f:

$$\beta = \frac{R_1}{R_1 + R_2} = \frac{10}{10 + 100} = \frac{1}{11} \Rightarrow$$

$$K_f = \frac{1}{1 + \frac{1}{\beta A_{OL}}} = \frac{1}{1 + \frac{11}{10^6}} = 0,999989 \Rightarrow$$

$$\text{Fejl}: \quad 1 - |K_f| = 1 - 0,999989 = 11 \cdot 10^{-6} = \underline{\underline{11\,\text{ppm}}}$$

Thevenin modstand ~ Udgangsmodstand



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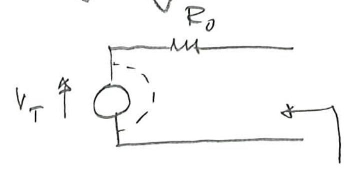
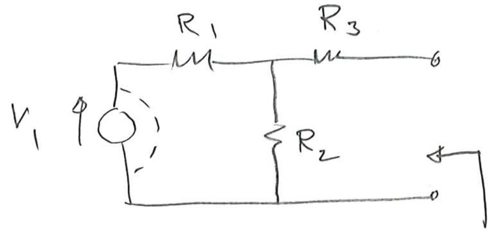


$R_T = R_0$

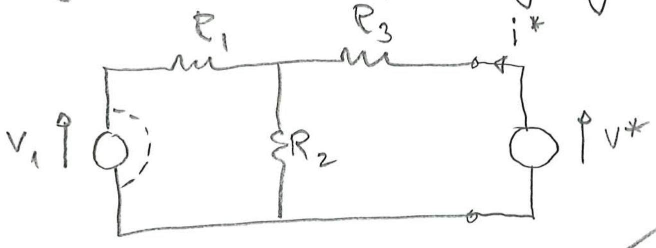
Princip: Uafhængige kilder nulstilles, og man "ser ind i den ækv. Thevenin modstand".

Ex



$R_T = R_0 = R_3 + R_1 \| R_2$

Denne modstand findes egentlig som et "v/i -forhold" for en generator sat på udgangen:



$$R_T = R_0 = \frac{v^*}{i^*}\Big|_{v_1=0}$$

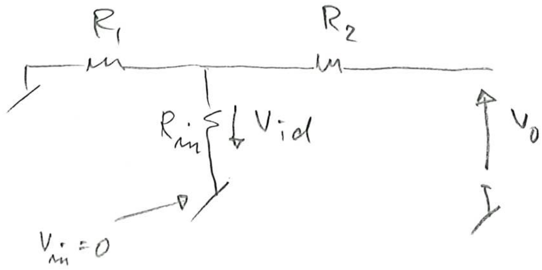
Metode til at finde R_0 med

Effekt af negativ feedback på Z_0, Z_{in} og A_{CL}

(se diagram på PPS)

Vi starter med at finde β (god idé til senere ☺)

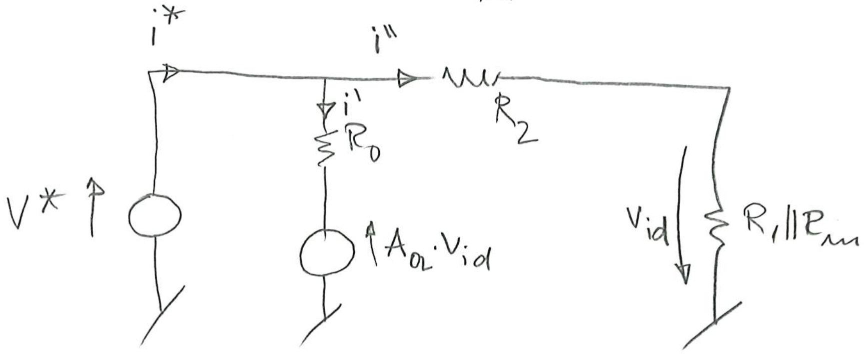
$$\beta = -\left.\frac{V_{id}}{V_0}\right|_{V_{in}=0}$$



$$V_{id} = -\frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}} \Rightarrow \beta = \frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}}$$

Udgangsmodstand Z_0 $(= R_T)$

$$Z_0 = \left.\frac{V^*}{i^*}\right|_{V_{in}=0}$$



$$① \quad i^* = i' + i''$$

$$② \quad i' = \frac{V^* - A_{OL} \cdot V_{id}}{R_0} \longrightarrow i' = \frac{V^* + \beta A_{OL} \cdot V^*}{R_0}$$

$$V_{id} = -V^* \cdot \frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}} = -\beta \cdot V^*$$

$$③ \quad i'' = \frac{V^*}{R_2 + R_1 \| R_{in}}$$

$$② + ③ \longrightarrow ① \quad \Rightarrow$$

$$i^* = \frac{V^* + \beta A_{OL} \cdot V^*}{R_0} + \frac{V^*}{R_2 + R_1 \| R_{in}} \quad \Rightarrow$$

$$\frac{i^*}{V^*} = \frac{1}{Z_0} = \frac{1 + \beta A_{OL}}{R_0} + \frac{1}{R_2 + R_1 \| R_{in}}$$

$$R_P = R_A \| R_B = \frac{1}{\frac{1}{R_A} + \frac{1}{R_B}}$$

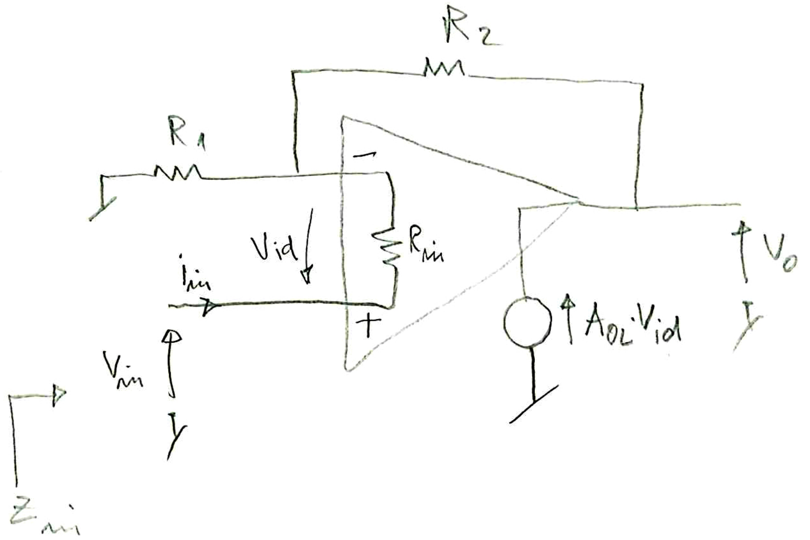
$$\frac{1}{R_P} = \frac{1}{R_A} + \frac{1}{R_B}$$

$$Z_0 = \underbrace{\frac{R_0}{1 + \beta A_{OL}}}_{[\mu\Omega] \to [m\Omega]} \Big\| \underbrace{(R_2 + R_1 \| R_{in})}_{[k\Omega]} \simeq \frac{R_0}{1 + \beta \cdot A_{OL}}$$

NB! $A_{OL} \to \infty \Rightarrow Z_0 \to 0\,\Omega$

Således negligeres R_0 i de følgende beregninger.

Indgangsmodstand Z_{in}



$$Z_{in} = \frac{V_{in}}{i_{in}}$$

$$V_{id} = e^+ - e^- = V_{in} - \beta \cdot V_o = V_{in} - \beta(A_{OL} \cdot V_{id}) \Rightarrow$$

$$V_{id} + \beta A_{OL} \cdot V_{id} = V_{in}$$

$$V_{id}(1 + \beta A_{OL}) = V_{in}$$

$$V_{id} = i_{in} \cdot R_{in} \Rightarrow$$

$$i_{in} \cdot R_{in}(1 + \beta A_{OL}) = V_{in} \Rightarrow$$

$$Z_{in} = \frac{V_{in}}{i_{in}} = \underline{\underline{R_{in}(1 + \beta A_{OL})}}$$

NB : $A_{OL} \rightarrow \infty \Rightarrow Z_{in} \rightarrow \infty$

Lukketsløjfeforstærkningen A_{CL}

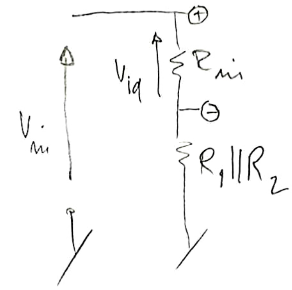
$$A_{CL} = \frac{\alpha}{\beta}\cdot K_f$$

$$K_f = \frac{1}{1+\frac{1}{\beta A_{OL}}}$$

Vi har:

$$\beta = \frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}}$$

$$\alpha = \left.\frac{V_{id}}{V_{in}}\right|_{V_0 = 0} \longrightarrow \alpha = \frac{R_{in}}{R_{in} + R_1 \| R_2}$$



$$\frac{\alpha}{\beta} = \frac{R_{in}}{R_{in} + R_1\|R_2}\cdot\frac{R_2 + R_1\|R_{in}}{R_1\|R_{in}} = \frac{R_{in}}{R_{in} + \frac{R_1\cdot R_2}{R_1+R_2}}\cdot\frac{R_2 + \frac{R_1\cdot R_{in}}{R_1+R_{in}}}{\frac{R_1\cdot R_{in}}{R_1+R_{in}}}$$

$$= \frac{\cancel{R_{in}}(R_1+R_2)}{\cancel{R_1R_{in}+R_2R_{in}+R_1R_2}}\cdot\frac{\cancel{R_1R_{in}+R_2R_{in}+R_1R_2}}{R_1\cdot\cancel{R_{in}}} = \frac{R_1+R_2}{R_1} = \underline{\underline{1+\frac{R_2}{R_1}}}$$

$A_{CL\,ideel}$

NB: Bemærk at R_{in} ikke indgår.

$A_{OL} \to \infty \Rightarrow V_{id} = 0 \Rightarrow$ ingen strøm i R_{in}

Således atter:

$$A_{OL} \to \infty \Rightarrow A_{CL} \to A_{CL\,ideel}$$

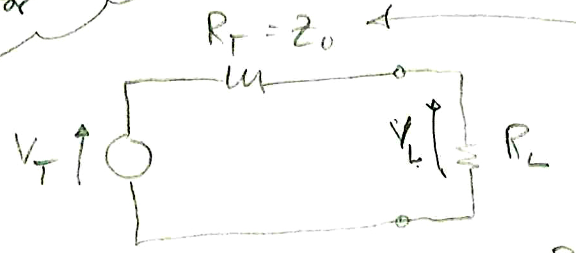
Evt. fejl/afvigelse (hvis A_{OL} <u>ikke</u> er uendelig) ligger i K_f.

Feedback typer

Hvordan skal kredsløbet se ud som kilde?

Set fra R_L

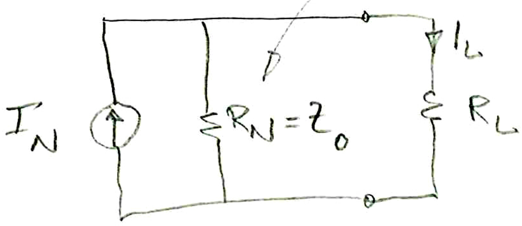
Ideel spændings-generator



Værdi af R_0 hvis V_L skal være konstant, selv om R_L varierer?

$R_0 = 0\,\Omega \Rightarrow V_L = V_T$

Ideel strøm-generator



Værdi af R_0 hvis I_L skal være konstant, selv om R_L varierer?

$R_0 \to \infty \Rightarrow I_L = I_N$

Hvordan skal kredsløbet se ud som belastning?

Set fra V_s

Husk her at fejlstørrelsen på figur 9.14:

V_i for spændingsfeedback

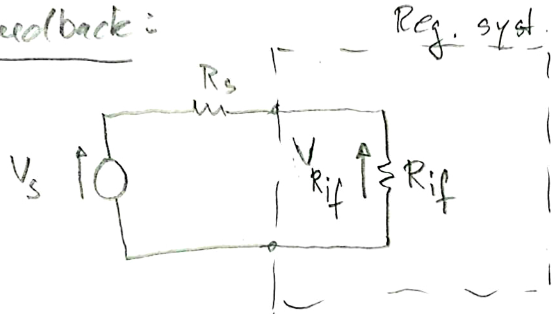
i_i for strømfeedback

skal reguleres mod 0.

Teknisk set (se figur 9.14), skal man altså opnå, at

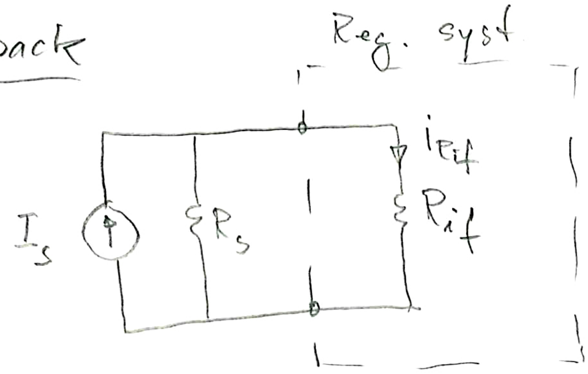
$$\boxed{\begin{array}{ll} V_f = V_s & \Rightarrow V_i = 0 \\ i_f = i_s & \Rightarrow i_i = 0 \end{array}}$$

Spændingsfeedback:



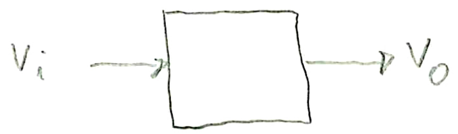
$R_{if} \to \infty \Rightarrow V_{R_{if}} = V_s$ uanset værdien af R_s

Strømfeedback



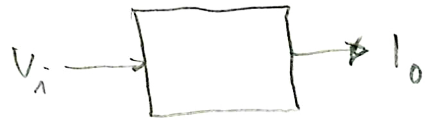
$R_{if} = 0\,\Omega \Rightarrow I_{R_{if}} = I_s$ uanset værdien af R_s

Forstærkertyper i reguleringssløjfen



$\frac{v_o}{v_i}\ [V/V] \longrightarrow A_v$

Spændingsforstærker

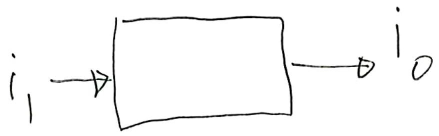


$\frac{i_o}{v_i}\ [A/V] \longrightarrow G_m$

Trans-konduktans

$\frac{v_o}{i_i}\ [V/A] \longrightarrow R_m$

Trans-impedans



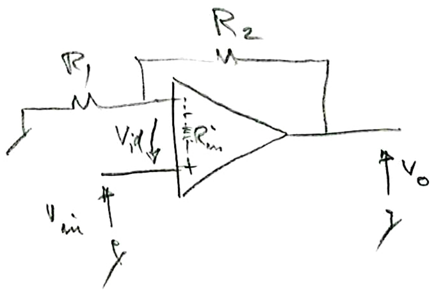
$\frac{i_o}{i_i}\ [A/A] \longrightarrow A_i$

Strømforstærker

Således i tabel 9.1 opfat følgende:

$$\text{"}A_v\text{"} = \text{"}G_m\text{"} = \text{"}R_m\text{"} = \text{"}A_i\text{"} = A_{OL}$$

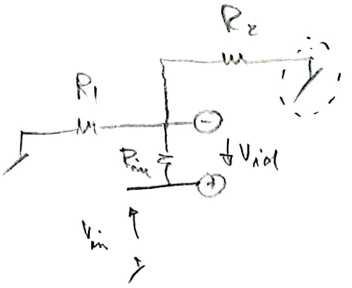
Sp. 5 fra forberedelsen

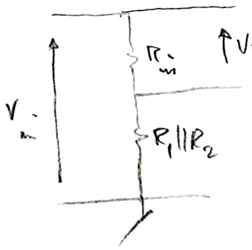


$R_1 = 10k\Omega$; $R_2 = 90k\Omega$; $R_{in} = 1M\Omega$

Max fejl pga. ikke ideel A_{OL} er 100ppm

$$\alpha = \left.\frac{v_{id}}{v_{in}}\right|_{v_o=0}$$

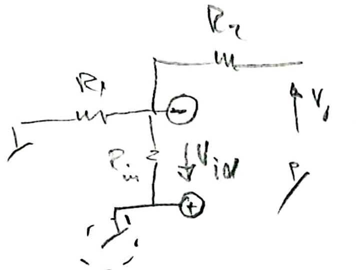


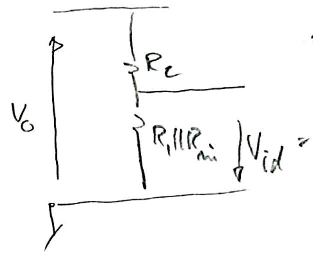


$$v_{id} = \frac{R_{in}}{R_{in} + R_1 \| R_2} \cdot v_{in} \Rightarrow$$

$$\alpha = \frac{R_{in}}{R_{in} + R_1 \| R_2} = \underline{0,991083}$$

$$\beta = -\left.\frac{v_{id}}{v_o}\right|_{v_{in}=0}$$





$$v_{id} = -\frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}} \cdot v_o \Rightarrow$$

$$\beta = \frac{R_1 \| R_{in}}{R_2 + R_1 \| R_{in}} = \underline{0,0991080}$$

$$\frac{\alpha}{\beta} = \frac{R_{in}}{R_{in} + \frac{R_1 \cdot R_2}{R_1 + R_2}} \cdot \frac{R_2 + \frac{R_1 \cdot R_{in}}{R_1 + R_{in}}}{\frac{R_1 \cdot R_{in}}{R_1 + R_{in}}}$$

$$= \frac{\cancel{R_{in}}(R_1 + R_2)}{\cancel{R_{in} R_1 + R_{in} R_2 + R_1 R_2}} \cdot \frac{\cancel{R_2 R_1 + R_2 R_{in} + R_1 R_{in}}}{R_1 \cdot \cancel{R_{in}}} = \frac{R_1 + R_2}{R_1} = \underline{\underline{10}}$$

NB!
Uafh. af R_{in} ...
hvorfor?

fejl = 100ppm $\Rightarrow 1 - |K_f| = 100 \cdot 10^{-6} \Rightarrow K_f = 999,900 \cdot 10^{-3}$

$$K_f = \frac{1}{1 + \frac{1}{\beta A_{OL}}} \Rightarrow \frac{1}{\beta A_{OL}} = \frac{1}{K_f} - 1 \Rightarrow A_{OL} = \frac{1}{\frac{1}{K_f} - 1} \cdot \frac{1}{\beta} \Rightarrow$$

$$A_{OL} = \frac{1}{\frac{1}{999,900 \cdot 10^{-3}} - 1} \cdot \frac{1}{0,0991080} = 100,89 \cdot 10^3 \cong \underline{101 \cdot 10^3 \,\hat{=}\, 100dB}$$

Dette er en minimumsværdi for A_{OL}!