Note: Quiz 12 - 6:30pm, Nov. 22, IEEE SSCS/CAS Chapter Leture - Dr. Eric Vittoz. Quiz will be to attend and submit to me by 11/24 a summary of what was said and your impressions.

Shunt-Shunt Feedback (Transresistance Amplifiers)

Approach to analyzing:

1.) Find $y_{11F} = \left.\frac{i_{1F}}{v_{1F}}\right|_{v_{2F}=0}$

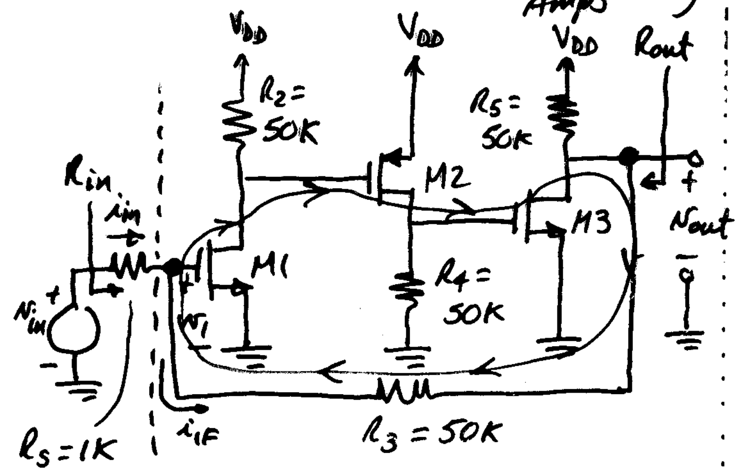
2.) Find $y_{22F} = \left.\frac{i_{2F}}{v_{2F}}\right|_{v_{1F}=0}$

3.) Find $y_{12F} = \left.\frac{i_{1F}}{v_{2F}}\right|_{v_{1F}=0}$

4.) Find A (note: it will have units of $\frac{\text{Volts}}{\text{Amps}} = \Omega$)

Example

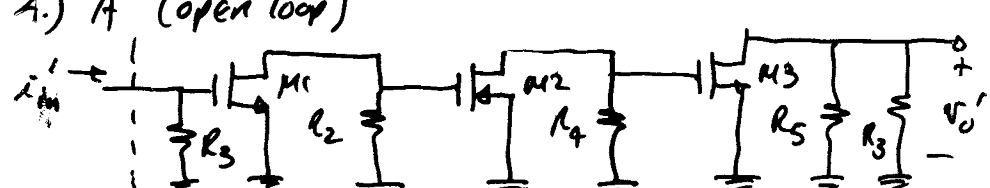
Find $\frac{v_{out}}{v_{in}}$, R_{in}, and R_{out} if $g_{m1} = g_{m2} = g_{m3} = 0.2$ mS and $r_{ds1} = r_{ds2} = r_{ds3} = \infty$.



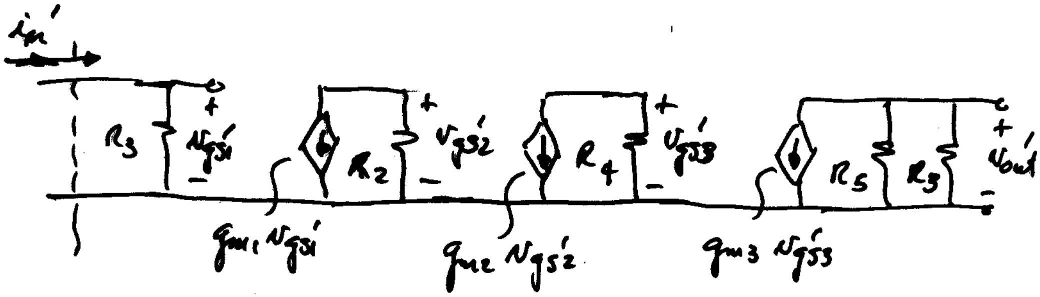
1.) $y_{11F} = \frac{1}{R_3} = \frac{1}{50K}$ 2.) $y_{22F} = \frac{1}{R_3} = \frac{1}{50K}$

3.) $y_{12F} = \left.\frac{i_{1F}}{v_{2F}}\right|_{v_{1F}=0} = \frac{-1}{50K}$

4.) A (open loop)



Example - Cont'd



$$A = \frac{v_{out}'}{i_{in}'} = \left(\frac{v_{out}'}{v_{gs3}'}\right)\left(\frac{v_{gs3}'}{v_{gs2}'}\right)\left(\frac{v_{gs2}'}{v_{gs1}'}\right)\left(\frac{v_{gs1}'}{i_{in}'}\right)$$

$$= (-g_{m3}R_3 \| R_5)(-g_{m2}R_4)(-g_{m1}R_2)(R_3) = -25\,M\Omega$$

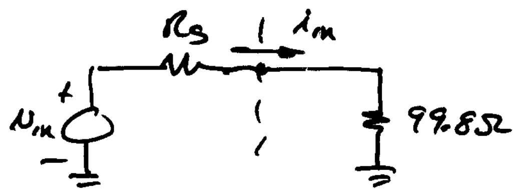
5.) $A_F = \dfrac{v_{out}}{i_{in}} = \dfrac{A}{1+AF} = \dfrac{-25\,M\Omega}{1+\frac{25\,M\Omega}{50\,K\Omega}} = \dfrac{-25\,M\Omega}{1+500} = -49.9\,K\Omega$

$R_{inF} = \dfrac{R_{in}}{1+AF} = \dfrac{R_3}{501} = \underline{\underline{99.8\,\Omega}}$

$R_{outF} = \dfrac{R_{out}}{1+AF} = \dfrac{R_3 \| R_5}{501} = \underline{\underline{49.9\,\Omega}}$

6.) Post-processing

$\dfrac{v_{out}}{v_{in}} = ?$



$$i_{in} = \frac{v_{in}}{R_S + R_{inF}} = \frac{v_{in}}{1099.8}$$

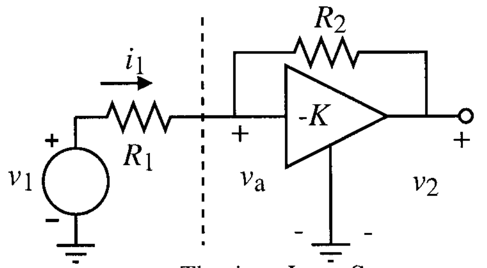
$$\therefore \frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{i_{in}}\right)\left(\frac{i_{in}}{v_{in}}\right) = (-49.9\,k\Omega)\frac{1}{1.0998\,k\Omega}$$

$$\frac{v_{out}}{v_{in}} = \underline{\underline{-45.5\,\tfrac{V}{V}}}$$

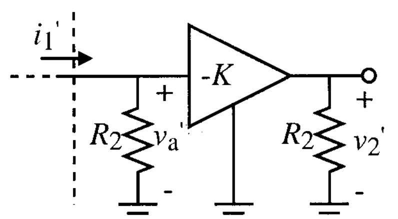
SHUNT INPUT FEEDBACK VERSUS A THEVINEN AND NORTON INPUT SOURCE

This example illustrates how to apply shunt-input feedback with either a Thevinen or Norton input source. The inverting voltage amplifier with a gain of K and infinite input and zero output resistance is shown in a shunt-shunt configuration but all results of this example are also applicable to shunt-series.

In the following, we will find the voltage gain, v_2/v_1, and the input resistance defined as v_1/i_1. The results for either case will be shown to be the same. The vertical dotted line illustrates the boundary for the feedback analysis method for either case.



Thevinen Input Source



Open-Loop Thevinen Input Source

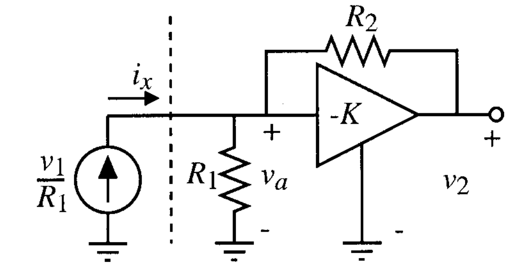
$$\beta = \frac{-1}{R_2}$$

$$v_2' = -KR_2 i_1' \Rightarrow \frac{v_2'}{i_1'} = R_T = -KR_2$$

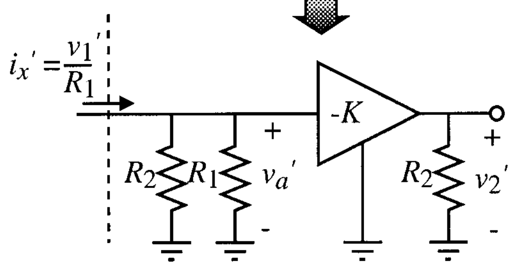
$$\frac{v_2}{i_1} = \frac{-KR_2}{1+(-KR_2)\left(\frac{-1}{R_2}\right)} = \frac{-KR_2}{1+K}$$

$$\frac{v_a}{i_1} = R_{inF} = \frac{R_2}{1+K}$$

$$\boxed{\frac{v_1}{i_1} = R_1 + R_{inF} = R_1 + \frac{R_2}{1+K}}$$



Norton Input



Open-Loop Norton Input

$$\beta = \frac{-1}{R_2}$$

$$v_2' = -K(R_1\|R_2)i_x' \Rightarrow \frac{v_2'}{i_x'} = R_T = -K(R_1\|R_2)$$

$$\frac{v_2}{i_1} = \frac{-K(R_1\|R_2)}{1+(-K(R_1\|R_2))\left(\frac{-1}{R_2}\right)} = \frac{-K\frac{R_1R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}$$

$$\frac{v_a}{i_x} = R_{inF} = \frac{\frac{R_1R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}$$

$$\frac{v_a}{i_x} = \frac{v_aR_1}{v_1} \text{ which gives,}$$

$$\frac{v_2}{v_1} = \frac{v_2}{i_1}\frac{i_1}{v_1} = \left(\frac{-KR_2}{1+K}\right)\left(\frac{1}{R_1 + \frac{R_2}{1+K}}\right)$$

$$= \frac{-KR_2}{R_1(1+K) + R_2} = \frac{-KR_2}{R_1 + R_2 + KR_1}$$

$$\boxed{\frac{v_2}{v_1} = -\frac{R_2}{R_1}\frac{\frac{KR_1}{R_1+R_2}}{1+\frac{KR_1}{R_2+R_1}}}$$

$$v_a = \frac{\frac{R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}\, v_1$$

i_1 can be expressed from the Thevinen form as,

$$i_1 = \frac{v_1}{R_1} - \frac{v_a}{R_1} = \frac{v_1}{R_1} - \frac{\frac{R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}\frac{v_1}{R_1}$$

$$\therefore \frac{i_1}{v_1} = \frac{1}{R_1}\left(1 - \frac{\frac{R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}\right)$$

$$= \frac{1}{R_1}\left(\frac{1+K\frac{R_1}{R_1+R_2} - \frac{R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}\right) = \frac{1+K}{R_1+R_2+KR_1}$$

Finally,

$$\boxed{\frac{v_1}{i_1} = R_1 + \frac{R_2}{1+K}}$$

Lastly,

$$\frac{v_2}{v_1} = \frac{v_2}{i_x}\frac{i_x}{v_1} = \frac{\frac{R_1R_2}{R_1+R_2}}{1+K\frac{R_1}{R_1+R_2}}\left(\frac{1}{R_1}\right)$$

$$\boxed{\frac{v_2}{v_1} = -\frac{R_2}{R_1}\frac{\frac{KR_1}{R_1+R_2}}{1+\frac{KR_1}{R_2+R_1}}}$$

So the results are identical although one method is a lot more work than the other.