IV. (40 pts): A voltage amplifier (A-amplifier) has an open-circuit voltage gain A_{v0} of 100V/V, an input resistance R_i of 250 $k\Omega$ and an output resistance R_0 of 1 $k\Omega$. It is connected in a negative feedback loop with a series-shunt topology.

When port 1 of the feedback network is open-circuited, the feedback network (looking from side 2) has an input resistance of 2 $k\Omega$.

When port 2 is short-circuited, the feedback network (looking from side 1) has an input resistance of 5 $k\Omega$.

The feedback factor is 0.1V/V.

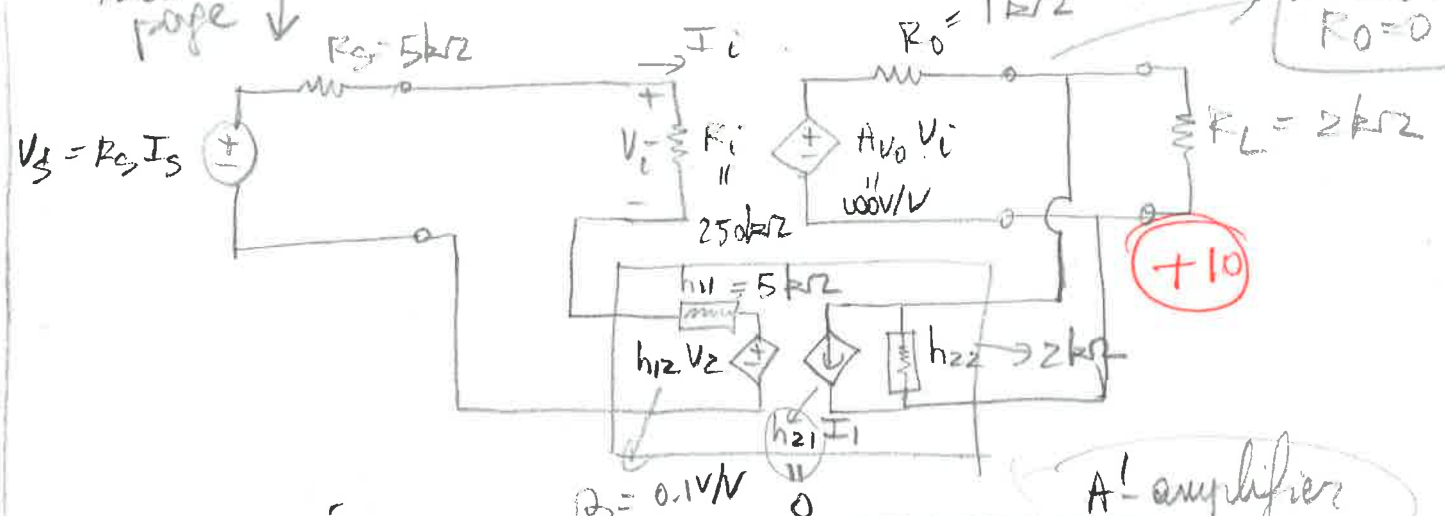
The amplifier is fed with a ~~current~~ voltage source with a resistance R_s of 5 $k\Omega$ and is feeding a load resistance R_L of 2 $k\Omega$.

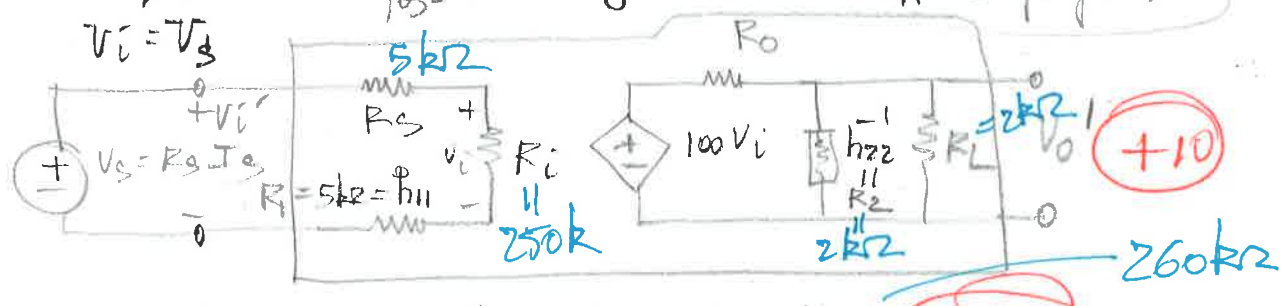
- Which small parameters should you use to model the feedback network? (+5)
- Draw the full circuit diagram inclusing source resistance, voltage amplifier, its feedback network, and the load resistance.
- Draw the $A^{'}$ amplifier and calculate its gain. Specify the units.
- Calculate the input resistance $R_i^{'}$ and output resistance $R_0^{'}$ of the $A^{'}$- amplifier.
- Finally, calculate the input resistance R_{if} and ouput resistance R_{of} of the amplifier with feedback.

$R_{if} = R_i'(1+\beta A')$
$R_{of} = R_0'/(1+\beta A')$

Ideal $R_i = \infty$, $R_0 = 0$

see next page





$R_i' = R_s + R_i + h_{11} = R_s + R_i + R_1 =$ (+2.5)

$R_o' (V_s = 0) = [R_L // h_{22}^{-1} // R_L] = [R_L // R_2 // R_L]$ (+2.5) $= 500\,\Omega$

$$V_i = \frac{R_i}{R_i + R_s + R_1} V_i'$$

$$V_o' = A_{vo} V_i \frac{(R_L \| R_2)}{[(R_L \| R_2) + R_o]}$$

$$A' = \frac{V_o'}{V_i'} = A_{vo} \frac{(R_L \| R_2)}{[(R_L \| R_2) + R_o]} \cdot \left[\frac{R_i}{R_i + R_s + R_1}\right] =$$

A_{vo} = 100 V/V

+5

$$A' = 100 \frac{1k\Omega}{1k\Omega + 1k\Omega} \cdot \left(\frac{250}{260}\right) = 48$$

$$1 + \beta_f A' = 1 + 0.1(48) = 5.8$$

$$R_{if} = R_i'(1 + A'\beta_f) = 260(5.8) = 1.5\,k\Omega$$ (2.5)

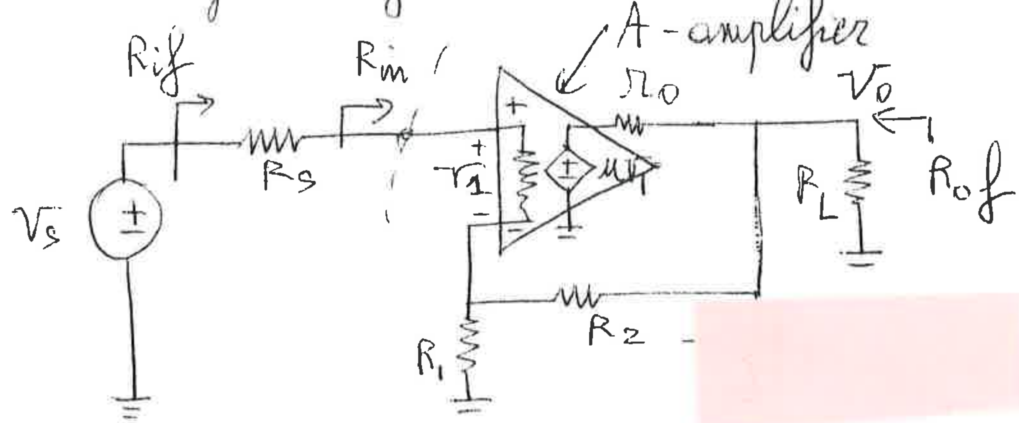
$$R_{of} = R_o'/(1 + A'\beta_f) = \frac{500\,\Omega}{(5.8)} = 86\,\Omega$$ (2.5)

Team members:

ECE352
SPRING 2011
Team Project 3

Due Monday May 9, 2011

Consider the following series-shunt configuration

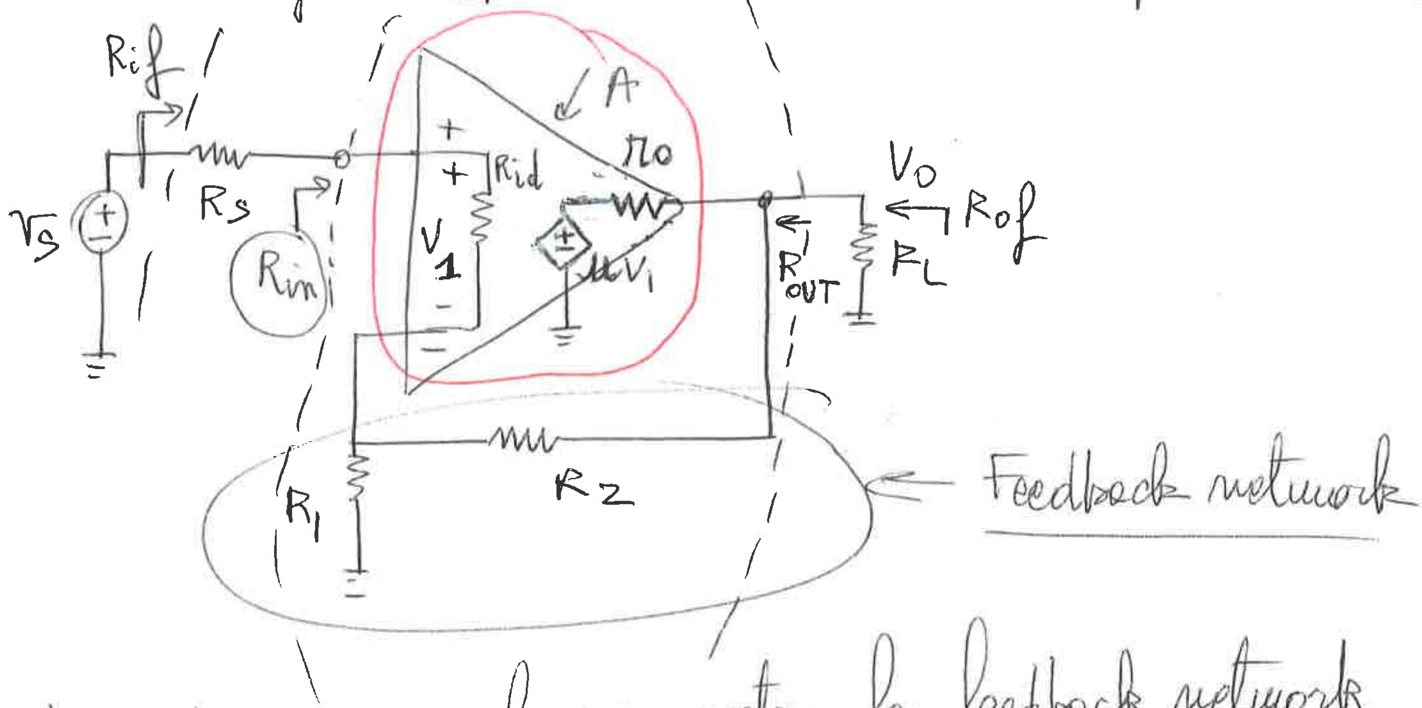


(a) Circle the feedback network
(b) Calculate the h-parameters for the feedback network
(c) Show how to build the A'-amplifier
(d) Calculate the gain of the A'-amplifier
(e) Calculate the gain $A_f = \frac{V_o}{V_S}$
(f) Determine the input and output resistances of the A'-amplifier
(g) Calculate the input (R_{if}) and output (R_{of}) resistances of the amplifier with feedback.

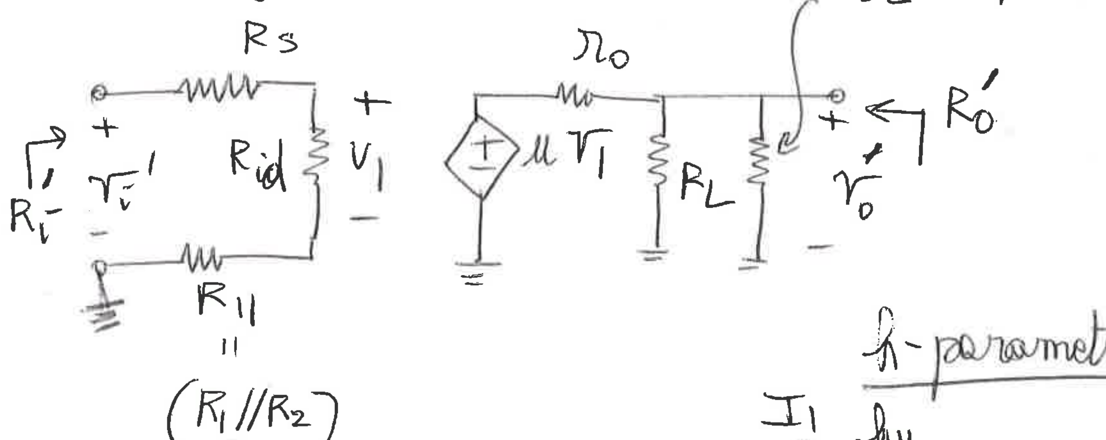
Use the following values in the calculations above

$R_{id} = 100\ k\Omega$ $\qquad R_1 = 1\ k\Omega$
$\mu = 10^4$ $\qquad R_2 = 1\ M\Omega$
$r_o = 1\ k\Omega$ $\qquad R_S = 10\ k\Omega$
$R_L = 2\ k\Omega$

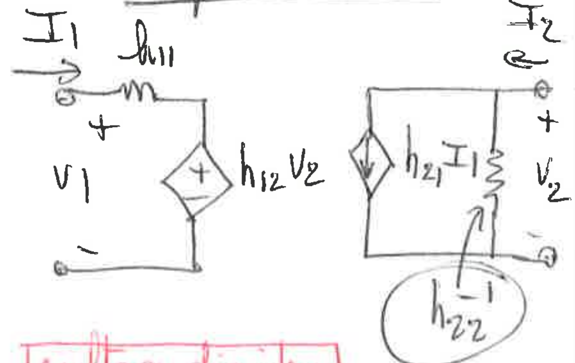
Find A' gain of A' circuit | Series-Shunt | Extra example



A' circuit — using h-parameters for feedback network.

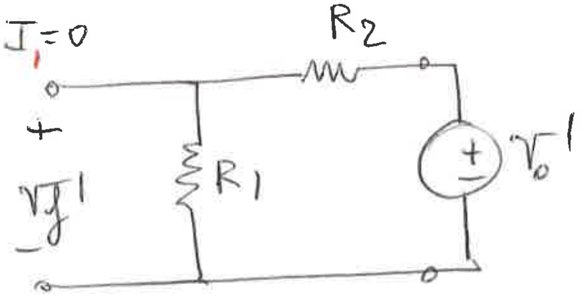


h-parameters



$R_{11} = h_{11}$ & $R_{22} = h_{22}^{-1} = R_1 + R_2$
from h-parameters analysis.

B_f?



Voltage divider

$$B_f = \frac{v_f'}{v_o'} = \frac{R_1}{R_1 + R_2}$$

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

A' = Gain of A' circuit is $\frac{v_o'}{v_i'}$

$$A' = \mu \frac{(R_L // R_{22})}{(R_L // R_{22}) + r_o} \cdot \frac{R_{id}}{[R_{id} + R_s + R_{11}]}$$

If
$R_{id} = 100\,k\Omega$
$\mu = 10^4$
$r_o = 1\,k\Omega$
$R_L = 2\,k\Omega$
$R_1 = 1\,k\Omega$
$R_2 = 1\,M\Omega$, $R_s = 10\,k\Omega$

$\rightarrow A' \simeq 6000\,V/V$

$$\beta_f = \frac{R_1}{R_1 + R_2} \simeq 10^{-3}\,V/V$$

∴ voltage gain with feedback is given by

$$A_f = \frac{v_o}{v_s} = \frac{A'}{1 + A'\beta_f} = \frac{6000}{7} = 857\,V/V$$

Input resistance with feedback

$$R_{if} = R_i(1 + A'\beta_f)$$

where R_i is the input resistance of A' circuit.

From previous page, we get

$$R_i = R_s + R_{id} + R_{11} = R_s + R_{id} + (R_1 // R_2) \simeq 111\,k\Omega$$

$\rightarrow$ $\boxed{R_{if} \simeq 777\,k\Omega}$

But $R_{in} + R_S = R_{if}$

$\rightarrow$ $R_{in} = R_{if} - R_S = \underline{739\,\Omega}$

$R_{of} = \dfrac{R_o'}{1 + A'\beta_f}$ where R_{out} is output resistance of A' circuit

$R_o' = r_o // R_L // (R_1 + R_2) \simeq 667\,\Omega$

$\rightarrow R_{of} = \dfrac{R_o'}{1 + \beta_f} = \dfrac{667}{7} \sim 95.3\,\Omega$

<u>But</u> $R_{of} = (R_L // R_{out})$

$\rightarrow$ $R_{out} \sim 100\,\Omega$

$\downarrow$

see how it is defined on diagram.