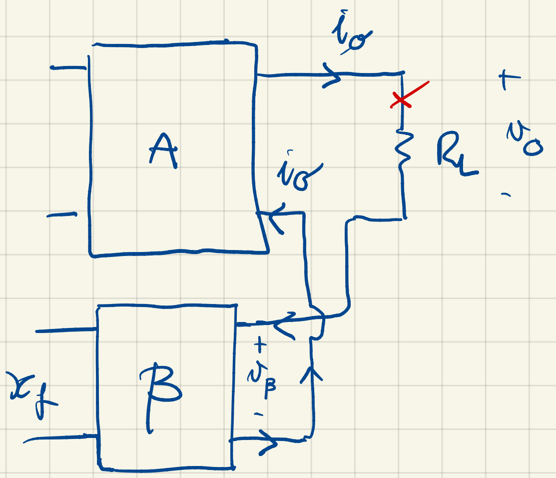
SERIES SENSING



IN THIS CASE THE β-NETWORK SENSES THE LOAD CURRENT i_o, LIKE IT WERE AN AMP-METER PLACED IN SERIES WITH THE LOAD

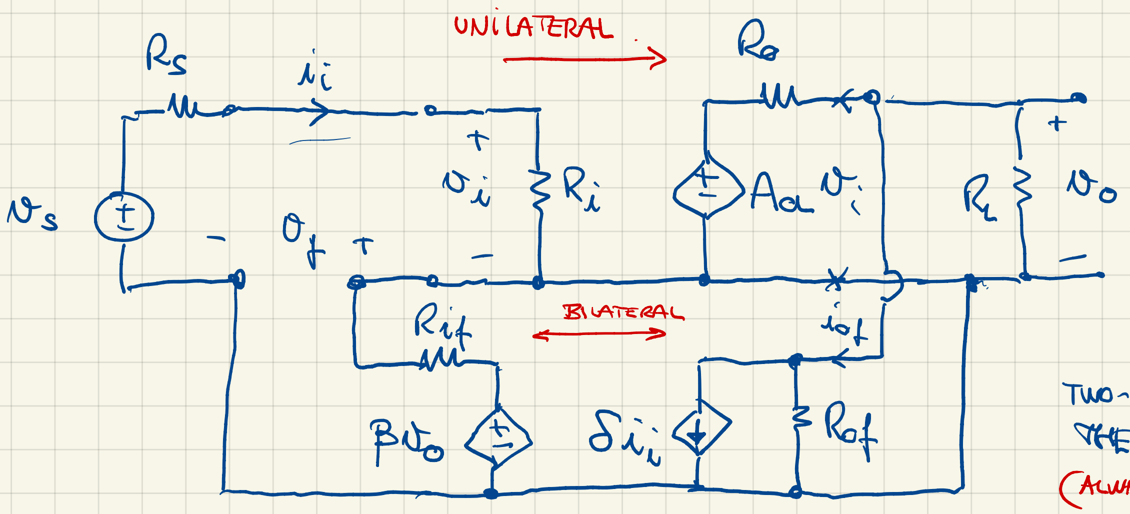
TO VERIFY IF SENSING IS SERIES TYPE, TRY TO CUT THE LOAD CONNECTION. IF x_f IS ZEROED THEN SENSING IS SERIES TYPE.

HERE $R_{out}^F \gg R_{out}$

SUMMARY

MIXING	SENSING	TOPOLOGY	A_F	R_{in}^F	R_{out}^F
SERIES	SERIES	TRANSCONDUCTANCE	$\dfrac{G_a}{1+\beta G_a}$	$R_{in}^a(1+\beta G_a)$	$R_{out}^a(1+\beta G_a)$
SERIES	SHUNT	VOLTAGE	$\dfrac{A_{OL}}{1+\beta A_{OL}}$	$R_{in}^a(1+\beta A_a)$	$\dfrac{R_{out}^a}{1+\beta A_a}$
SHUNT	SERIES	CURRENT	$\dfrac{A_{OL}}{1+\beta A_{OL}}$	$\dfrac{R_{in}^a}{1+\beta A_{OL}}$	$R_{out}^a(1+\beta A_a)$
SHUNT	SHUNT	TRANSRESISTANCE	$\dfrac{R_{ol}}{1+\beta R_{ol}}$	$\dfrac{R_{in}^{OL}}{(1+\beta R_a)}$	$\dfrac{R_{out}^{ol}}{(1+\beta R_a)}$

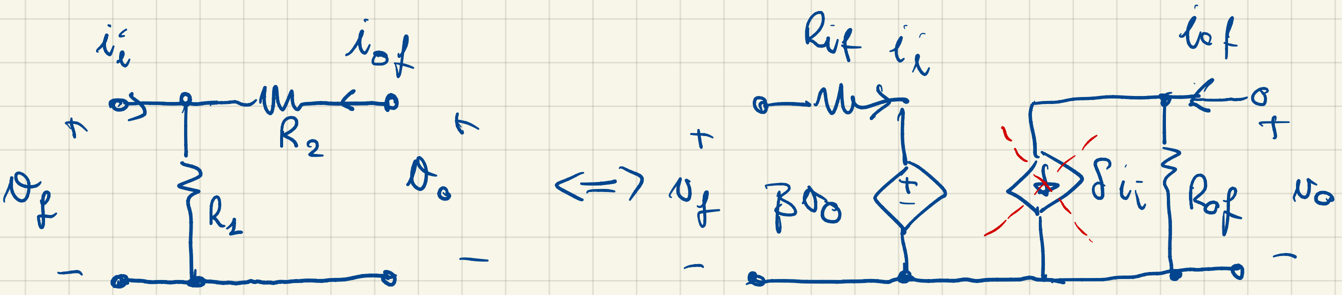
LET'S CONSIDER THE VOLTAGE AMPLIFIER IN MORE DETAIL:



TWO PORT OF THE AMPLIFIER (TYPICALLY UNILATERAL)

TWO-PORT MODEL OF THE β-NETWORK (ALWAYS BILATERAL)

EXAMPLE OF A TYPICAL BETA-NETWORK



β-NETWORK — TWO-PORT MODEL OF β-NETWORK

IN ORDER TO BE EQUIVALENT TO THE PHYSICAL β-NETWORK, THE MODEL PARAMETERS ARE AS FOLLOWS

$$R_{if} \triangleq \frac{v_f}{i_i}\Big|_{v_o=\emptyset} = R_1 /\!/ R_2 \qquad \beta \triangleq \frac{v_f}{v_o}\Big|_{i_i=\emptyset} = \frac{R_1}{R_1+R_2}$$

$$R_{of} \triangleq \frac{v_o}{i_{of}}\Big|_{i_i=\emptyset} = R_1+R_2 \qquad \delta \triangleq \frac{i_{of}}{i_i}\Big|_{v_o=\emptyset} = -\frac{R_1}{R_1+R_2}$$

IN THE TYPICAL CASE, WE WILL ASSUME $\delta \cong \emptyset$ (WHICH, IN GENERAL, MAKES LITTLE SENSE !!). THE REASON CAN BE SEEN BY COMPARING THE TWO PATHS THAT FEED THE OUTPUT FROM THE INPUT PORT. IN THE VOLTAGE AMPLIFIER, THIS AMOUNTS TO COMPARING THE SHORT CIRCUIT CURRENTS:

$$\frac{A_a v_i}{R_o} \quad \text{AND} \quad \delta i_i = \delta \cdot \frac{v_s}{R_s+R_{if}+R_i}$$

$$v_i = v_s \cdot \frac{R_i}{R_i+R_{if}+R_s}$$

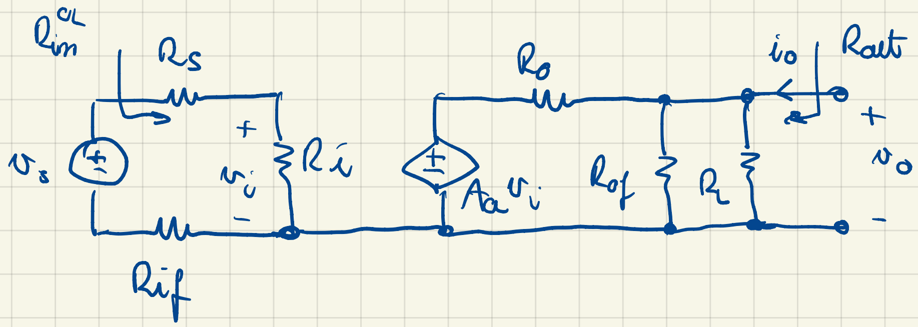
$$A_a \cdot \frac{R_i}{R_o} \cdot \cancel{\frac{v_s}{R_i+R_{if}+R_s}} \quad \overset{??}{<>} \quad \delta \cdot \cancel{\frac{v_s}{R_s+R_{if}+R_i}}$$

WE CAN SAY THAT δ CAN BE NEGLECTED ANY TIME

$$\delta \ll A_a \frac{R_i}{R_o}$$

WHICH IS THE TYPICAL CASE FOR A VOLTAGE AMPLIFIER AS $A_a \gg 1$ $\frac{R_i}{R_o} \gg 1$ WHILE $\delta \leq 1$ (β-NETWORK IS PASSIVE)

LET'S ANALYSE THE AMPLIFIER IN OPEN LOOP CONDITIONS $\Rightarrow \beta = \delta = \emptyset$



$$A_v^{a} \triangleq \left.\frac{v_o}{v_s}\right|_{\beta=\delta=\emptyset} = \underbrace{\frac{R_i}{R_s + R_i + R_{if}}}_{\alpha_i} \cdot A_a \cdot \underbrace{\frac{R_{of} \parallel R_L}{R_o + R_{of} \parallel R_L}}_{\alpha_o} = \alpha_i A_a \alpha_o$$

$$R_{in}^{a} \triangleq \left.\frac{v_s}{i_i}\right|_{\beta=\delta=\emptyset} = R_s + R_i + R_{if}$$

$$R_{out}^{OL} \triangleq R_o \parallel R_{of} \parallel R_L$$

WE CAN NOW ACTIVATE FEEDBACK: $\beta \neq \emptyset$ $\quad \delta = \emptyset$ APPROXIMATION !!

$$A_v^{F} = \left.\frac{v_o}{v_s}\right|_{\beta\neq 0,\, \delta=0} = \frac{A_v^{a}}{1 + \beta A_v^{a}}$$

AS WE EXPECTED FROM THE TABLE SUMMARY

$$\begin{cases} v_o = \alpha_o \cdot A_a \cdot v_i \\ v_i = (v_s - \beta v_o) \cdot \alpha_i \end{cases} \Rightarrow v_o = \alpha_o A_a \alpha_i v_s - \alpha_i A_a \alpha_o \beta v_o \Rightarrow$$

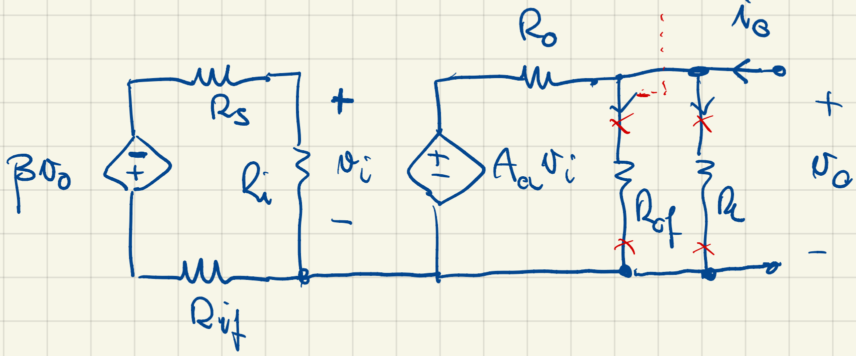
$$\Rightarrow \underbrace{v_o \left(1 + \beta \cdot \underbrace{\alpha_i A_a \alpha_o}_{A_v^{a}}\right)}_{1 + T \text{ FOR THIS AMPLIFIER}} = A_v^{a} v_s \Rightarrow \dots$$

THE ABOVE RESULT

$$R_{in}^{F} = \left.\frac{v_s}{i_i}\right|_{\beta\neq 0,\, \delta=\emptyset} = R_{in}^{OL}\left(1 + \beta A_v^{a}\right)$$

$$i_i = \frac{v_s - \beta v_o}{R_s + R_i + R_{if}} = \frac{v_s - v_s \cdot \frac{\beta A_v^a}{1+\beta A_v^a}}{\underbrace{R_s + R_i + R_{if}}_{R_{in}^a}} = \frac{v_s}{R_{in}^a\,(1+\beta A_v^a)} \Rightarrow \cdots$$

$$R_{out}^F = \left.\frac{v_o}{i_o}\right|_{\substack{\beta\neq 0,\ \delta=0 \\ v_s=\emptyset}} = \frac{R_{out}^a}{1+\beta A_v^a}$$



$$R_{out}^F = R_L /\!/ R_{of} /\!/ R_x = R_L /\!/ R_{of} /\!/ \frac{R_o}{1+\alpha_i \beta A_a}$$

$$R_x \triangleq \left.\frac{v_o}{i_o}\right|_{R_L = R_{of} = +\infty} \qquad i_o = \frac{v_o - A_a v_i}{R_o} = \frac{v_o + v_o \beta \alpha_i A_a}{R_o} \Rightarrow$$

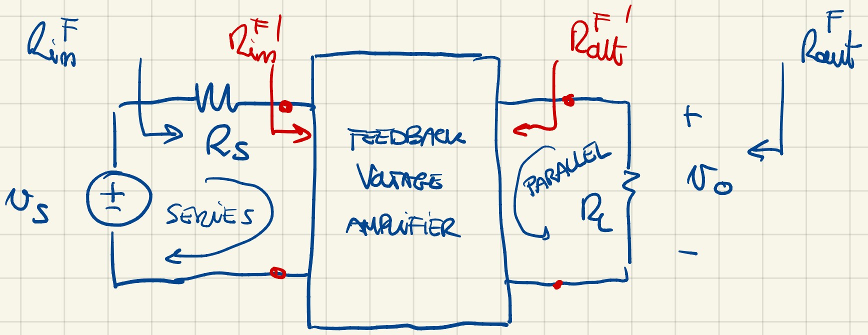
$$R_x = \frac{v_o}{i_o} = \frac{R_o}{1+\alpha_i \beta A_a}.$$

THEREFORE

$$R_{out}^F = \frac{(R_L /\!/ R_{of}) \cdot \frac{R_o}{1+\alpha_i\beta A_a}}{R_L /\!/ R_{of} + \frac{R_o}{1+\alpha_i \beta A_a}} = \frac{R_o \cdot (R_L /\!/ R_{of})}{R_L /\!/ R_{of} + R_L /\!/ R_{of}\, \alpha_i \beta A_a + R_o} =$$

$$= \underbrace{\frac{R_o\,(R_L /\!/ R_{of})}{R_o + R_L /\!/ R_{of}}}_{R_{out}^a} \cdot \frac{1}{1 + \underbrace{\beta A_a \alpha_i \cdot \underbrace{\frac{R_L /\!/ R_{of}}{R_L /\!/ R_{of} + R_o}}_{\alpha_o}}_{T}} = \frac{R_{out}^a}{1+T} \quad \blacksquare$$

WHAT HAPPENS IF...



... WE LOOK FOR INPUT AND OR OUTPUT RESISTANCES THAT DO NOT APPEAR AT THE APPROPRIATE SECTION OF THE AMPLIFIER, SUCH AS :

$R_{in}^{F'}$ AND $R_{out}^{F'}$

$\left.\begin{array}{l} A_v^F \; R_{in}^F \\ R_{out}^F \end{array}\right\}$ GIVEN BY THE ABOVE ANALYSIS

$$R_{in}^F = R_s + R_{in}^{F'} \implies R_{in}^{F'} = R_{in}^F - R_s$$ DISASSEMBLING THE SERIES

THE INPUT PORT HAS SERIES STRUCTURE (SINGLE LOOP)

THE RESULT IS NOT EQUIVALENT TO $(R_i + R_{if})(1 + \beta A_v^{ol}) \neq R_{in}^{F'}$

THIS TERM INCLUDES R_s

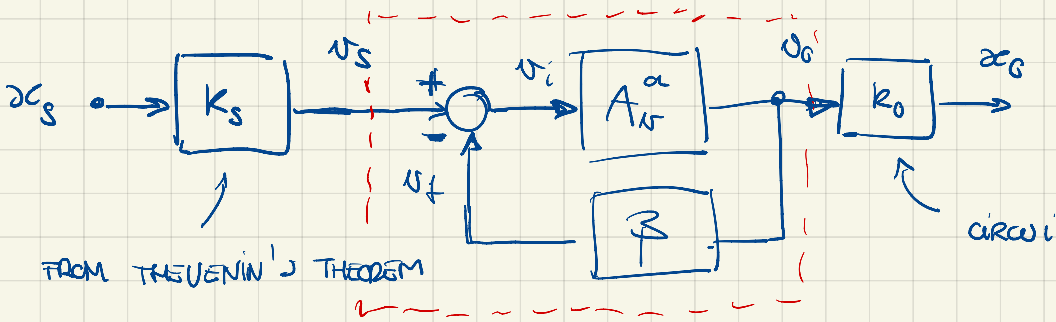
$$R_{out}^F = R_L \,//\, R_{out}^{F'} \implies R_{out}^{F'} = \frac{1}{\frac{1}{R_{out}^F} - \frac{1}{R_L}}$$

THE OUTPUT HAS PARALLEL STRUCTURE (SINGLE NODE)

THIS IS NOT EQUIVALENT TO $R_{of} \,//\, R_o \cdot \frac{1}{1 + \beta A_v^{ol}} \neq R_{out}^{F'}$

THIS TERM INCLUDES R_L

FINAL NOTE: OFTEN, THE SOURCE OF THE SIGNAL MUST BE TURNED INTO A THEVENIN STRUCTURE .... $\implies$ SCALING FACTORS ARE INTRODUCED:



$$\frac{x_o}{x_s} = k_s \cdot A_v^F \cdot k_o$$

$v_s = k_s x_s \qquad x_o = k_o v_o$

$$A_v^F \triangleq \frac{v_o}{v_s} = \frac{x_o}{k_o} \cdot \frac{1}{k_s x_s} \implies \frac{x_o}{x_s} = k_s A_v^F k_o$$