$$A = \frac{v_o}{i_s} = -A_a \cdot Z_s \| Z_{if} = -A_a \cdot Z_s \| Z_2 \qquad (\beta = 0)$$

$$A_F = \frac{v_o}{i_s} = \frac{A}{1 + \beta A} = -\frac{A_a \; Z_s \| Z_2}{1 + \frac{1}{Z_2} \cdot A_a \cdot Z_s \| Z_2}$$

$$A_v = \frac{v_o}{v_s} = \frac{v_o}{i_s} \cdot \frac{i_s}{v_s} = A_F \cdot \frac{1}{Z_s} = -\underbrace{\frac{Z_s \| Z_2}{Z_s}}_{\frac{Z_2}{Z_2 + Z_s}} \cdot \frac{A_{ol}(s)}{\underbrace{1 + A_{ol}(s) \frac{Z_s \| Z_2}{Z_2}}_{1 + \underbrace{A_{ol} \cdot \frac{Z_s}{Z_s + Z_2}}_{T}}}$$

$T \gg 1$:

$$\simeq -\frac{Z_s \| Z_2}{Z_s} \cdot \frac{Z_2}{Z_s \| Z_2} = -\frac{Z_2}{Z_s}$$

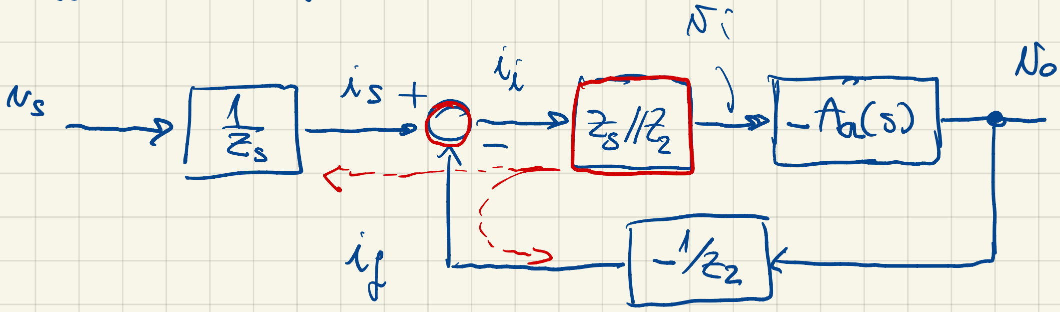
$$Z_s = \frac{1}{sC} \quad \& \quad Z_2 = R$$

$$T = A_{ol}(s) \cdot \frac{Z_s}{Z_s + Z_2} = \frac{1}{1 + sRC} \cdot A_{ol}(s)$$

THIS IS EXACTLY THE SAME T FOUND WITH DIRECT LOOP INSPECTION

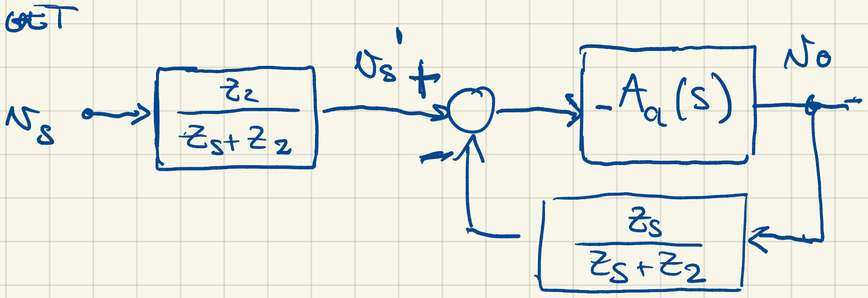
◇ T IS A PROPERTY OF THE CIRCUIT, SO IT MUST BE THE SAME NO MATTER THE ANALYTICAL APPROACH WE TAKE

LET'S DRAW THE BLOCK DIAGRAM THAT TRANSLATES THE EQUIVALENT CIRCUIT.



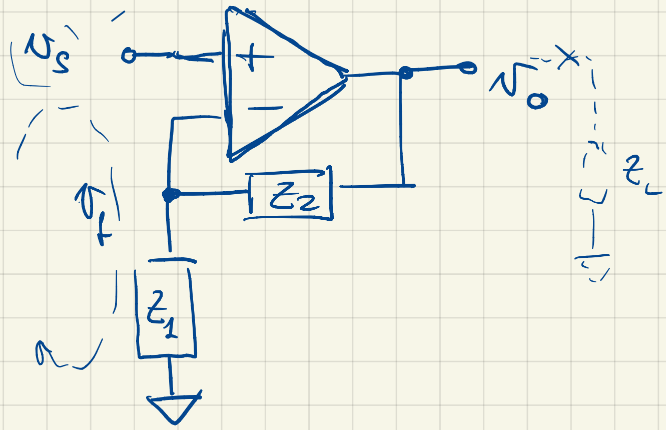

THIS BLOCK DIAGRAM SHOWS ONLY SIGNALS THAT WE CAN IDENTIFY ON THE EQUIVALENT CIRCUIT

BY APPLYING BLOCK DIAGRAM ALGEBRA WE CAN MODIFY IT TO GET




THIS BLOCK DIAGRAM DIRECTLY COMES FROM LOOP INSPECTION

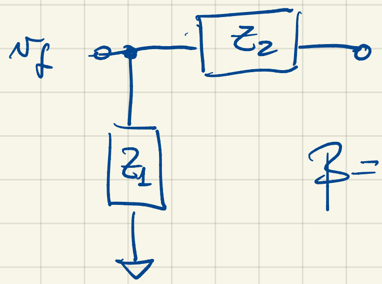
JUST ANOTHER OBSERVATION: NON INVERTING CONFIGURATION

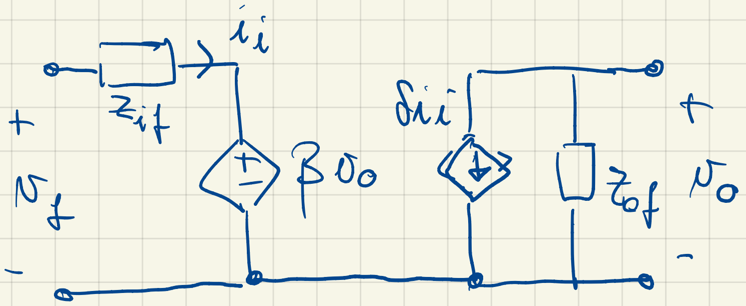



LET'S DRAW THE BLOCK DIAGRAM OF THIS CIRCUIT BASED ON FEEDBACK THEORY

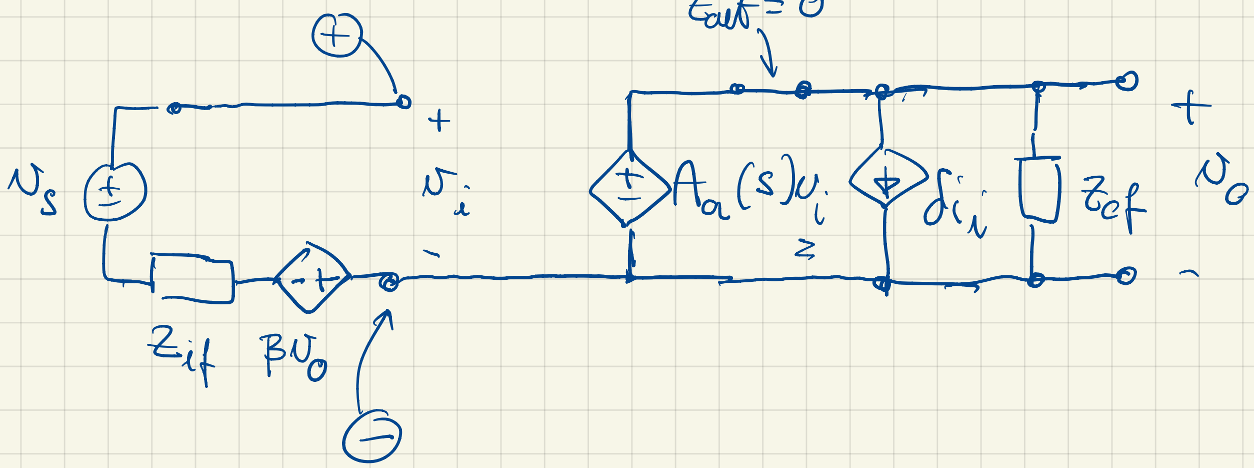
THIS IS A CASE OF VOLTAGE AMPLIFIER

$\beta$ IS THE NETWORK THAT GENERATES $v_f$ FROM $v_o$




$$\beta = \frac{Z_1}{Z_2 + Z_1}$$




AGAIN, BECAUSE THE AMPLIFIER HAS $Z_{out} = 0$ AND $Z_{in} = +\infty$ LOADING EFFECTS ARE ZERO

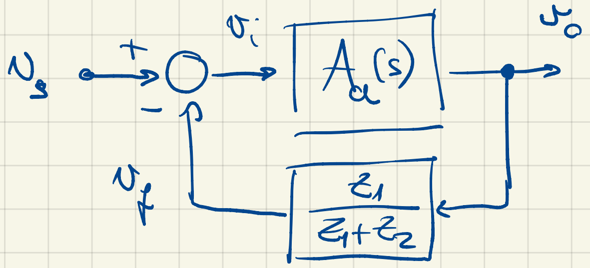
THEREFORE $A$, THE OPEN LOOP AMPLIFICATION, IS EXACTLY EQUAL TO $A_a$

$$A = A_a \qquad (\beta = \emptyset)$$

$$A_f = \frac{A}{1+\beta A} = \frac{A}{1 + A \cdot \frac{Z_1}{Z_1+Z_2}} = A_v$$

$T = A \cdot \frac{Z_1}{Z_1+Z_2}$ WHEN $T \gg 1$ THEN $A_v \cong 1 + \frac{Z_2}{Z_1}$ ∎

THE BLOCK DIAGRAM, IN THIS CASE, IS




IT IS THE SAME BLOCK DIAGRAM FOUND BY DIRECT LOOP INSPECTION

IN CONCLUSION, WHEN WE ANALYSE OPAMP CIRCUIT STABILITY IT IS EQUIVALENT TO USE FEEDBACK THEORY OR DIRECT LOOP INSPECTION BECAUSE **T** IS THE SAME.

IN THE GENERAL CASE, IT IS NORMALLY FASTER TO USE DIRECT LOOP INSPECTION

IN CASE THE AMPLIFIER HAS $Z_{in} \neq +\infty$ AND/OR $Z_{out} \neq 0$ THEN IT IS GENERALLY FASTER TO USE FEEDBACK THEORY BECAUSE LOADING EFFECTS HAVE TO BE TAKEN INTO ACCOUNT.

IN ANY CASE $A_N(s)$ IS ALWAYS $\cong \dfrac{1}{\beta(s)}$ WHERE $\underline{\underline{|T| \gg 1}}$

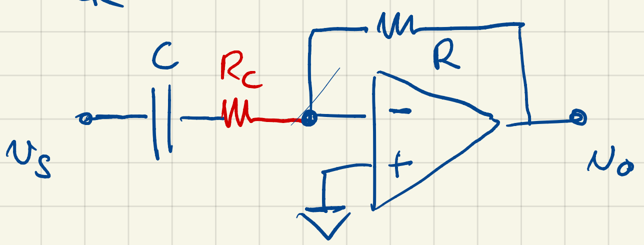
LET'S GO BACK TO THE DIFFERENTIATOR CIRCUIT. BASED ON THE ANALYSIS WE SEE

$$\beta(s) = \frac{1}{1+sRC} = \frac{1}{1+s/\omega_{RC}} \longrightarrow \frac{1+s/\omega_z}{1+s/\omega_{RC}} = \beta_c(s)$$

WHICH, COMBINED TO $A_a(s) = \dfrac{A_{a0}}{1+\dfrac{s}{\omega_0}}$ YIELDS $PM \cong 0$

A POSSIBLE SOLUTION TO GET AT LEAST $PM = +45^0$ IS TO PLACE A ZERO AT $\omega_z = \omega_{CR}$.

$$\beta_c(s) = \frac{\frac{1}{sC} + R_c}{R + R_c + \frac{1}{sC}}$$



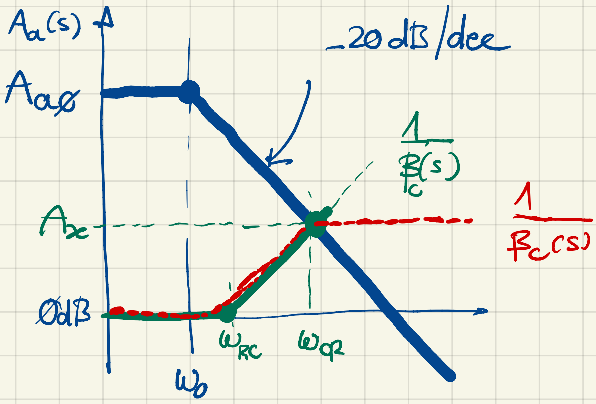

$$\beta_c(s) = \frac{1+sR_cC}{1+sC(R+R_c)}$$

THE POLE IS MOVED TO THE LEFT

BUT IF $R_C << R$ $(R_C+R)C \simeq RC$ SO THE POLE WILL MOVE BY A NEGLIGIBLE AMOUNT.

LET'S ASSUME $R_C << R$ AND FIND $\omega_{CR}$

$$\begin{cases} A_{ol0} \cdot \omega_0 = A_x \cdot \omega_{CR} \\ \dfrac{1}{\omega_{RC}} = \dfrac{A_x}{\omega_{CR}} \end{cases}$$



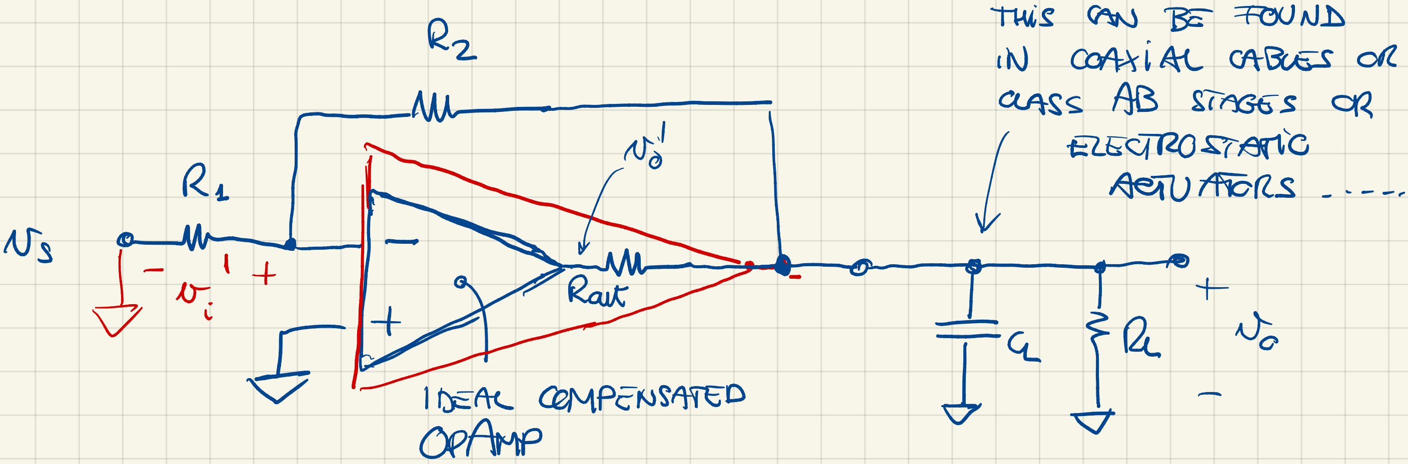

$$\omega_{CR} = \sqrt{A_{ol0}\, \omega_0\, \omega_{RC}}$$

$$\omega_z = \frac{1}{R_C C} = \omega_{CR} \Rightarrow R_C = \frac{1}{\omega_{CR} C}$$

FINAL STEP: VERIFY $R_C << R$.

THE SAME PROBLEM IS MET WHEN WE ARE DEALING WITH CAPACITIVELY LOADED OPAMP CIRCUITS.

IN THIS CASE THE PROBLEM IS DUE TO THE NON ZERO OUTPUT RESISTANCE OF THE OPAMP



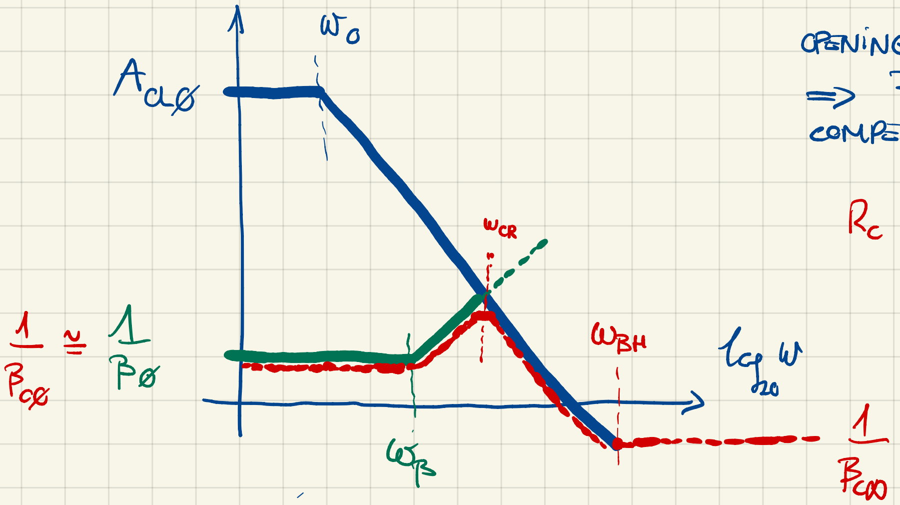

THIS CAN BE FOUND IN COAXIAL CABLES OR CLASS AB STAGES OR ELECTROSTATIC ACTUATORS ....

THE COMBINATION OF A CAPACITIVE LOAD AND $R_{out} \neq 0$ IS GOING TO GENERATE STABILITY PROBLEMS.

LET'S FIND $\beta(s)$ IN THIS CIRCUIT

$$\beta(s) = \left.\frac{v_i'}{v_o'}\right|_{v_s=0} = \frac{v_i'}{v_o} \cdot \frac{v_o}{v_o'} = \frac{R_1}{R_1+R_2} \cdot \frac{\overbrace{R_L /\!/ (R_1+R_2)}^{R_L'}}{R_{out} + R_L /\!/ (R_1+R_2)} \cdot \frac{1}{1+sC_L R_{CL}}$$

$$R_{CL} = R_{out} /\!/ (R_1+R_2) /\!/ R_L = R_L' /\!/ R_{out}$$

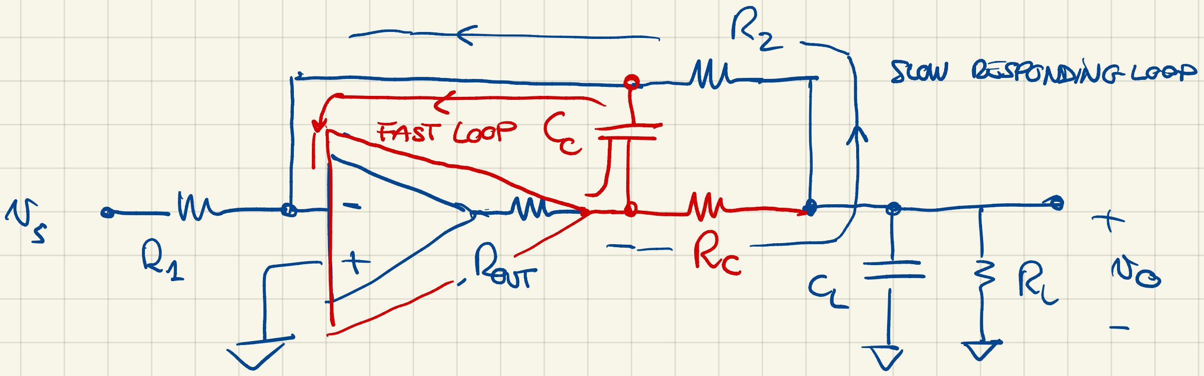



OPENING AND CLOSING RATIOS ARE $\pm 40$ dB/dec
$\Rightarrow$ PM $\simeq \emptyset$ $\Rightarrow$ WE NEED TO APPLY COMPENSATION!

$R_c < R_{out}$

$$\omega_B = \frac{1}{R_{CL} \cdot C_L}$$

A POSSIBLE COMPENSATION NETWORK IS THE FOLLOWING




THE IDEA IS TO BY-PASS THE DELAYED FEEDBACK CREATING A FAST FEEDBACK PATH THAT STABILYZES THE AMPLIFIER TURNING IT INTO A FOLLOWER.