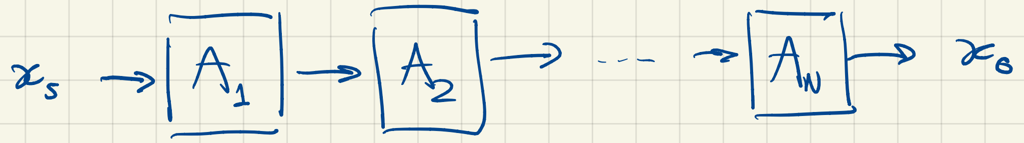
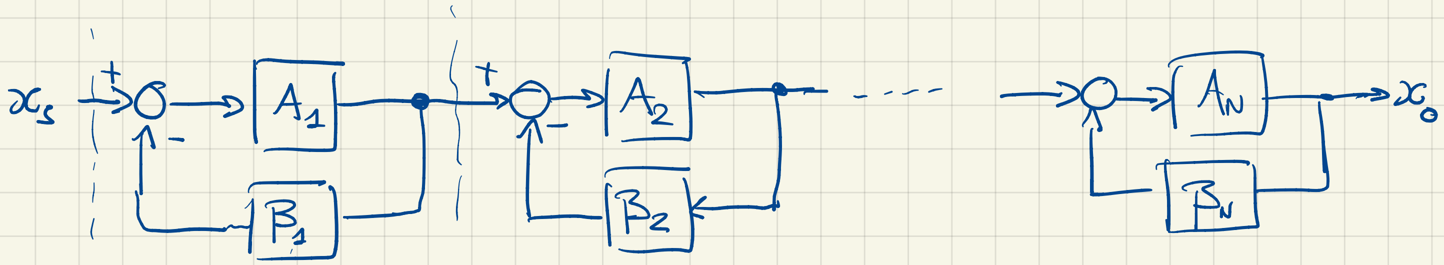
FEEDBACK THEORY APPLICATION NOTES

1. MULTI - STAGE AMPLIFIER TOPOLOGIES

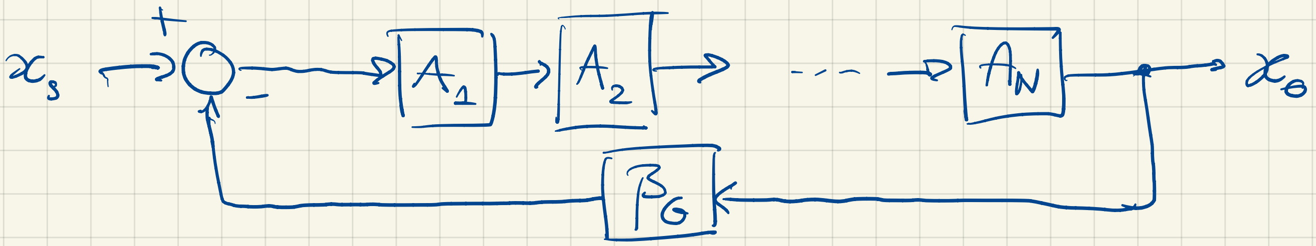


- FEEDBACK ARRANGEMENTS ARE BASICALLY :
  - LOCAL FEEDBACK
  - GLOBAL FEEDBACK



LOCAL FEEDBACK

TO SIMPLIFY WE ASSUME $A_1 = A_2 = \dots A_N = A_{CL}$ AND $\beta_1 = \beta_2 = \dots \beta_N = \beta_L$



GLOBAL FEEDBACK

UNDER THE ABOVE ASSUMPTIONS GLOBAL FEEDBACK IS MORE DIFFICULT TO STABILIZE EVEN WHEN

$$A_{OL} = \frac{A_{OL\,MB}}{1 + \frac{s}{\omega_p}}$$

IS A SINGLE POLE DYNAMIC SYSTEM

LOCAL FEEDBACK, IN THE SAME CONDITIONS, HAS NO STABILITY ISSUES.

SENSITIVITY OF THE CLOSED LOOP GAIN:

$$A_{FL} = \frac{A_{ol}^N}{(1+\beta_L A_{ol})^N} \qquad \text{FOR LOCAL FEEDBACK}$$

$$A_{FG} = \frac{A_{ol}^N}{1+\beta_G A_{ol}^N} \qquad \text{FOR GLOBAL FEEDBACK}$$

FOR A FAIR COMPARISON, WE NEED TO ASSUME THAT $A_{FG} \equiv A_{FL} \Rightarrow$

$$(1+\beta_L A_{ol})^N \equiv 1+\beta_G A_{ol}^N$$

SENSITIVITY IS DEFINED AS

$$> \quad S_{A_F}^{A_{ol}} = \frac{\partial A_F}{\partial A_{ol}} \cdot \frac{A_{ol}}{A_F}$$

WE COULD ALSO CONSIDER

$$S_{A_F}^{\beta} = \frac{\partial A_F}{\partial \beta} \cdot \frac{\beta}{A_F} = -\frac{A_{ol}^{\cancel{2}}}{(1+\beta A_{ol})^{\cancel{2}}} \cdot \frac{\beta}{\cancel{A_{ol}}} \cdot \cancel{(1+\beta A_{ol})} = -\frac{A_{ol}\beta}{1+A_{ol}\beta}$$

$$A_F = \frac{A_{ol}}{1+\beta A_{ol}}$$

$S_{A_F}^{\beta} \cong -1$ ANY TIME $A_{ol} \cdot \beta \gg 1$ (THE TYPICAL CASE)

ANY ERROR OR TOLERANCE OR DRIFT THAT MODIFIES β, MODIFIES A_F BY THE SAME AMOUNT (ONLY THE SIGN IS OPPOSITE).

THEREFORE: β-NETWORKS MUST BE IMPLEMENTED WITH VERY STABLE COMPONENTS, WITH LOW TOLERANCE ...

LET'S GO BACK TO $S_{A_F}^{A_{ol}}$

$$S_{A_{FL}}^{A_{ol}} = N \cdot \frac{A_{ol}^{N-1}}{(1+\beta_L A_{ol})^{N-1}} \cdot \frac{1+\beta_L A_{ol} - \beta_L A_{ol}}{(1+\beta_L A_{ol})^2} \cdot \frac{A_{ol}}{A_{FL}} = N \cdot \frac{\cancel{A_{ol}^N}}{(1+\beta_L A_{ol})^{N+1}} \cdot \frac{\cancel{(1+\beta_L A_{ol})^N}}{\cancel{A_{ol}^N}} =$$

$$= N \cdot \frac{1}{1+\beta_L A_{ol}}$$

$$S^{A_a}_{A_{FG}} = \frac{N\cdot A_a^{N-1}\left(1+\beta_G A_a^N\right) - N\cdot\beta_G A_a^{N-1} A_a^N}{\left(1+\beta_G A_a^N\right)^2}\cdot\frac{A_a\cancel{\left(1+\beta_G A_a^N\right)}}{A_a^N} =$$

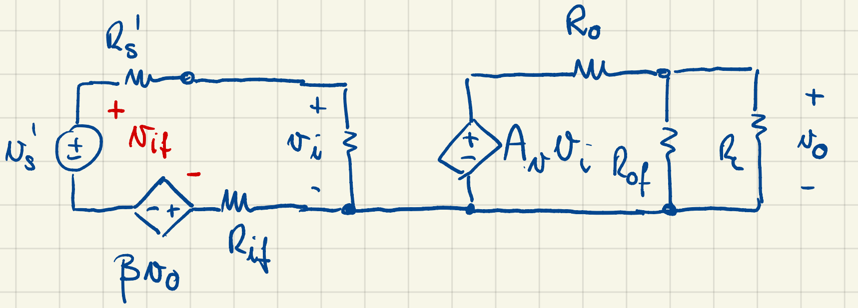
$$= \frac{N\cancel{A_a^{N-1}} + \cancel{N\beta_G A_a^{2N-1}} - \cancel{N\beta_G A_a^{2N-1}}}{\left(1+\beta_G A_a^N\right)\cancel{A_a^{N-1}}} = \frac{N}{1+\beta_G A_a^N} \overset{\downarrow}{=} \frac{N}{\left(1+\beta_L A_a\right)^N}$$

$$S^{A_a}_{A_{FG}} = \underbrace{\left(S^{A_a}_{A_{FL}}\right)^N}_{<1}\cdot\underbrace{\frac{1}{N^{N-1}}}_{\ll 1} \ll S^{A_a}_{A_{FL}}$$

GLOBAL FEEDBACK IS VERY ADVANTAGEOUS (WITH RESPECT LOCAL FEEDBACK) IN TERMS OF SENSITIVITY. IT IS LESS ADVANTAGEOUS IN TERMS OF STABILITY

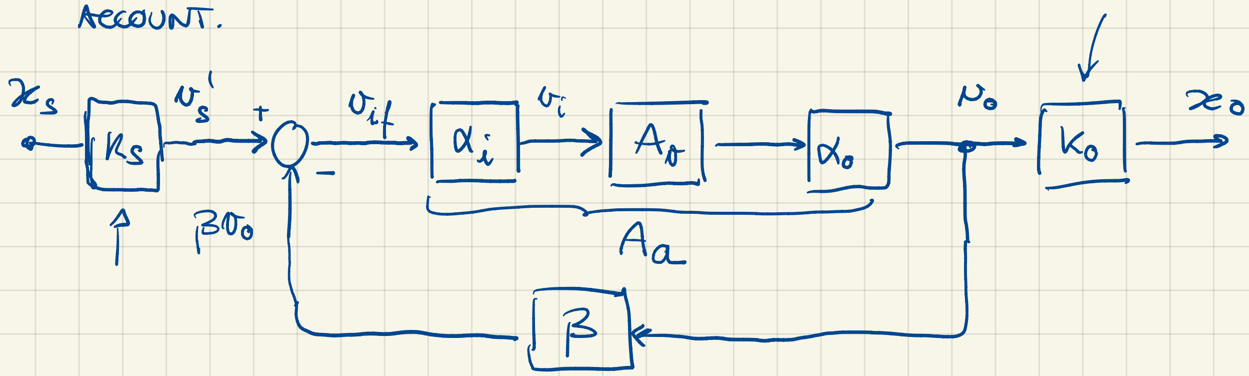
BECAUSE THERE'S NO CLEAR WINNER, BOTH SOLUTIONS ARE USED, OFTEN AT THE SAME TIME.

◊ BLOCK DIAGRAMS OF FEEDBACK AMPLIFIERS. (RELATION BETWEEN FEEDBACK THEORY AND CONTROL SYSTEM THEORY)



EQUIVALENT CIRCUIT OF A VOLTAGE AMPLIFIER WITH FEEDBACK

FROM THIS CIRCUIT, WE CAN IMMEDIATELY DERIVE A BLOCK DIAGRAM WHERE LOADING EFFECTS AND SCALE FACTORS ARE TAKEN INTO ACCOUNT.



$$\alpha_i = \frac{R_i}{R_i + R_s' + R_{if}} \qquad \alpha_o = \frac{R_L /\!/ R_{of}}{R_o + R_L /\!/ R_{of}} \qquad A_a = \alpha_i A_v \alpha_o$$

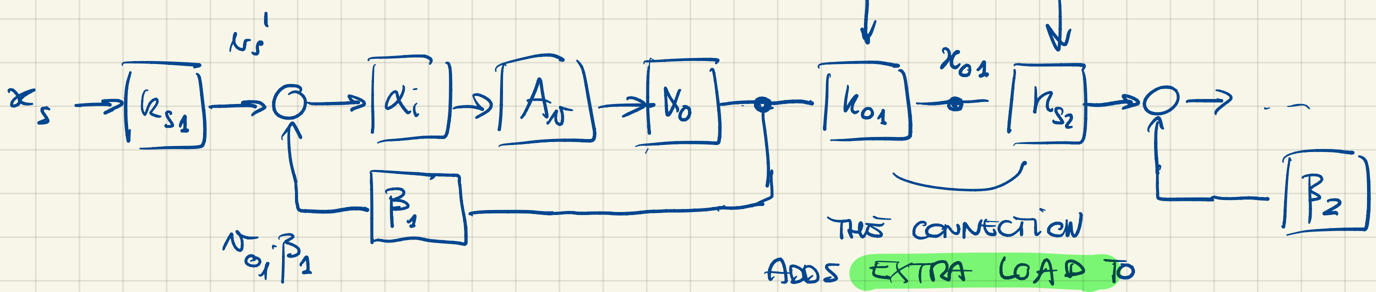
IT IS THEN POSSIBLE TO INTERCONNECT BLOCK DIAGRAMS TO TREAT COMPLEX AMPLIFIER ORGANIZATIONS SUCH AS:

- CASCADE ORGANIZATION
- NESTED LOOP ORGANIZATION
- INTERTWINED LOOP ORGANIZATION

BUT CARE MUST BE TAKEN TO ACCOUNT FOR LOADING EFFECTS

1. CASCADE

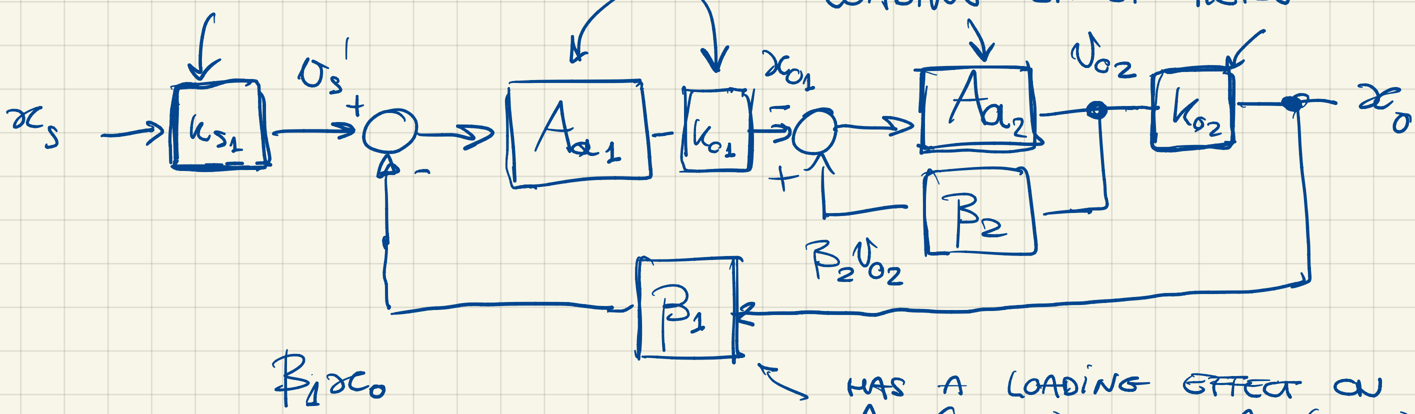
THESE MUST BE CALCULATED CONSIDERING THE LOADING EFFECTS



THIS CONNECTION ADDS EXTRA LOAD TO A_1

2. NESTED LOOP

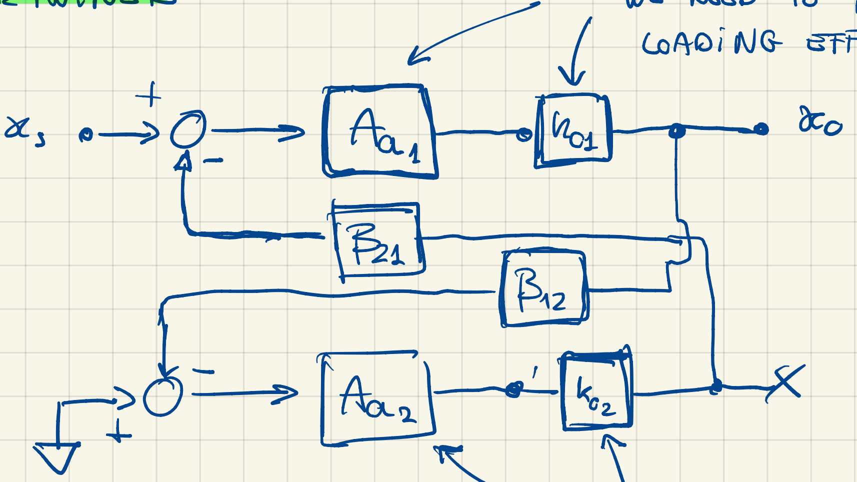
WE NEED TO TAKE INTO ACCOUNT LOADING EFFECTS HERE



HAS A LOADING EFFECT ON A_2 (OUTPUT) AND A_1 (INPUT)

3. INTERTWINED

WE NEED TO TAKE LOADING EFFECTS INTO ACCOUNT



LOADING EFFECTS

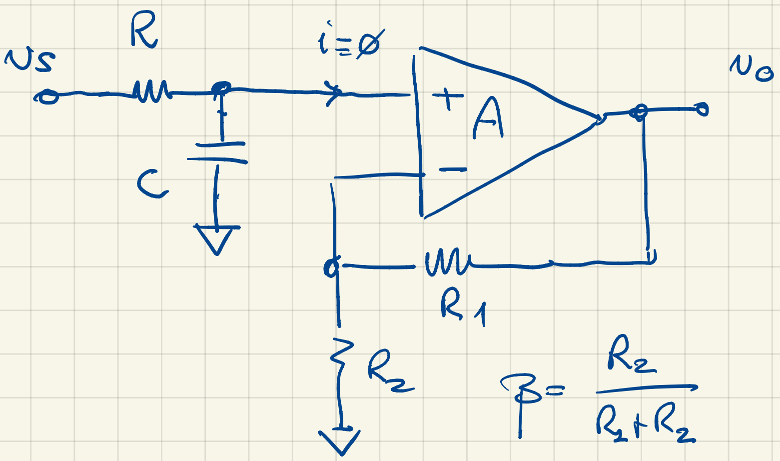
β_{21} LOADS THE INPUT SIDE OF A_1 AND THE OUTPUT SIDE OF A_2

β_{12} LOADS THE INPUT SIDE OF A_2 AND THE OUTPUT SIDE OF A_1

FEEDBACK AND FREQUENCY RESPONSE

IN GENERAL TERMS, THE BANDWIDTH WIDENING PROPERTY HOLDS, BUT CARE MUST BE TAKEN BEFORE APPLYING SUCH PROPERTY TO ANY AMPLIFIER

CONSIDER THIS EXAMPLE:



$$\beta = \frac{R_2}{R_1+R_2}$$

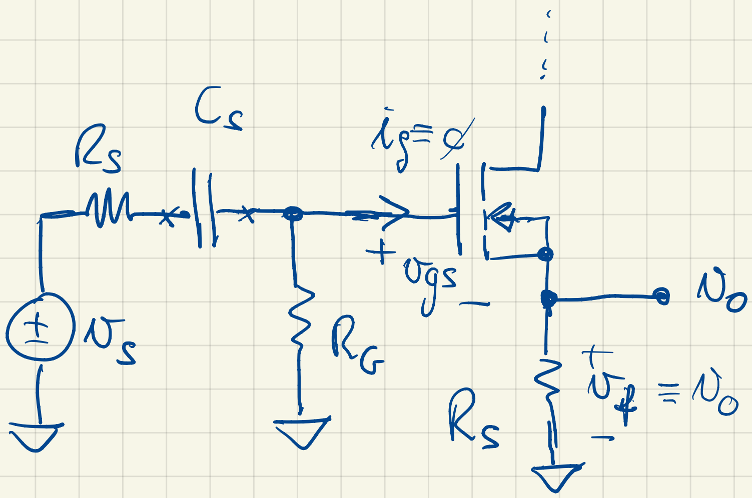
SINGLE POLE PLACED AT

$$\omega_p = \frac{1}{RC}$$

WHICH OBVIOUSLY DOES NOT DEPEND ON T OR $1+T = 1+A\beta$

THE REASON THE POLE DOES NOT DEPEND ON T IS THAT IT IS PLACED OUTSIDE THE FEEDBACK LOOP. ACTUALLY, THE POLE IS LOCATED INSIDE K_S

LET'S CONSIDER ANOTHER EXAMPLE



$v_f = v_o \Rightarrow \beta = 1$

$$\omega_p = \frac{1}{C_s(R_s+R_G)}$$

AGAIN, THE POLE DOES NOT DEPEND ON T

INDEED C_s "SEES" THE SAME RESISTANCE R_s+R_G NO MATTER THE VALUE OF T

FEEDBACK THEORY AND STABILITY

USING FEEDBACK THEORY WE CAN CALCULATE A_a AND β EXACTLY. THEREFORE WE CAN ALSO FIND $\underline{\underline{T = \beta A_a}}$.

ONCE WE HAVE T, WE CAN USE NYQUIST THEOREM AND

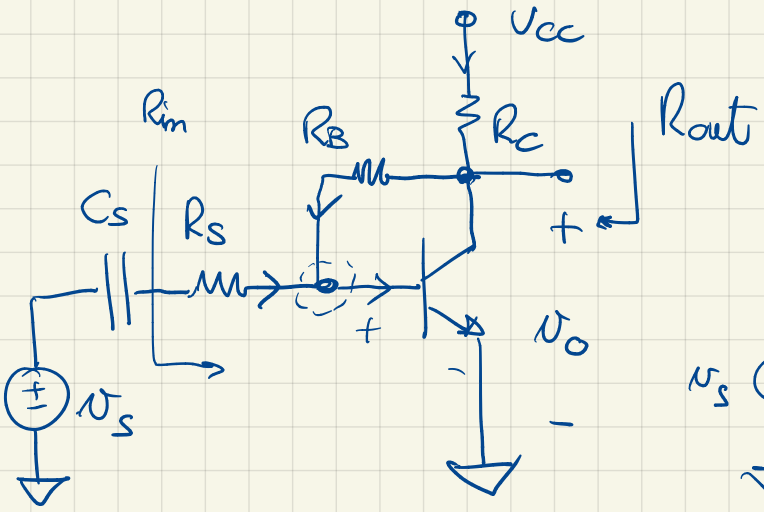
DISCUSS THE AMPLIFIER STABILITY.

BUT WE CAN ALSO SHAPE THE B-NETWORK TO ENHANCE THE AMPLIFIER'S STABILITY MARGINS (PHASE MARGIN AND/OR GAIN MARGIN)

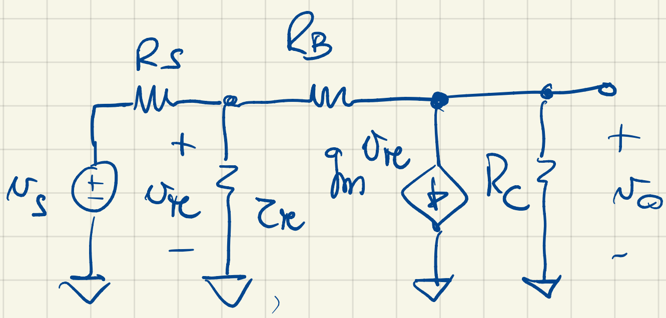
THIS IS CALLED COMPENSATION OF AN AMPLIFIER. THIS WILL BE THE OBJECT OF NEXT LESSONS.

EXAMPLE

CE AMPLIFIER WITH SELF-BIAS



SMALL SIGNAL EQUIVALENT CIRCUIT @ MID-BAND



1. FIND $A_v \triangleq \frac{v_o}{v_s}$, R_{in} AND R_{out}
2. DISCUSS THE POLE LOCATION
3. DRAW THE AMPLIFIER BLOCK DIAGRAM.