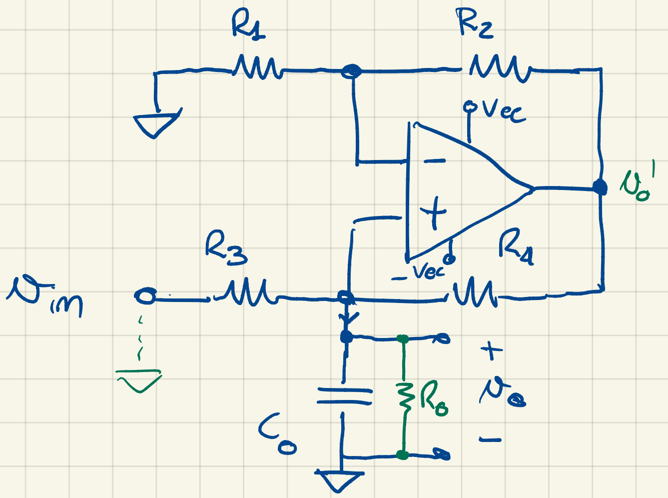
8/11/2022

FEEDBACK IN ELECTRONIC AMPLIFIERS

IN ELECTRONICS WE USE BOTH NEGATIVE AND POSITIVE FEEDBACK



EXAMPLE: NON INVERTING INTEGRATOR

Hyp: OPAMP is IDEAL

$R_1 = R_3$

$R_2 = R_4$

AS A RESULT (PROOF AS EXERCISE)

$$v_o = v_{in} \cdot \frac{1}{sC_oR_1}.$$

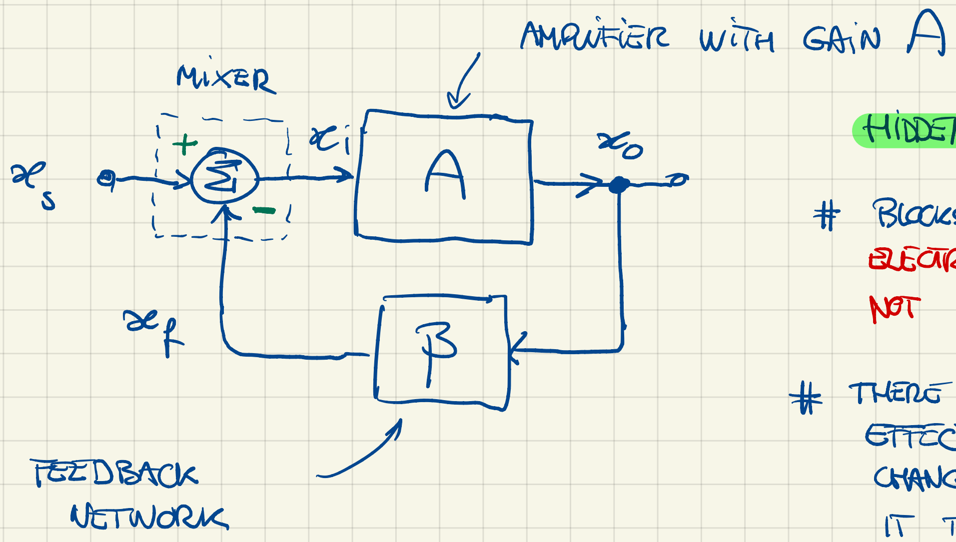
PROBLEM:

@ DC $\quad v_- = \frac{R_1}{R_1+R_2} v_o' = v_+ \Rightarrow$ POTENTIAL STABILITY ISSUE

SOLUTION:

BY APPLYING R_o (LARGE) WE MAKE NEGATIVE FEEDBACK STRONGER THAN THE POSITIVE ONE

THE MODEL OF A FEEDBACK AMPLIFIER CAN BE THE USUAL ONE, BASED ON BLOCK DIAGRAMS



HIDDEN ASSUMPTIONS

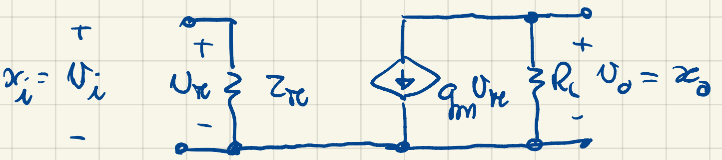
\# BLOCKS ARE UNILATERAL
ELECTRONIC CIRCUITS ARE NOT UNILATERAL (IN GENERAL)

\# THERE ARE NO LOADING EFFECTS (A DOES NOT CHANGE WHEN WE CONNECT IT TO β)
ALL ELECTRONICS CIRCUITS SHOW SOME DEGREE OF LOADING EFFECT $\Rightarrow$ A DOES CHANGE WHEN CONNECTED TO β

EXAMPLES

1. A is A CE STAGE
2. A is A CC STAGE

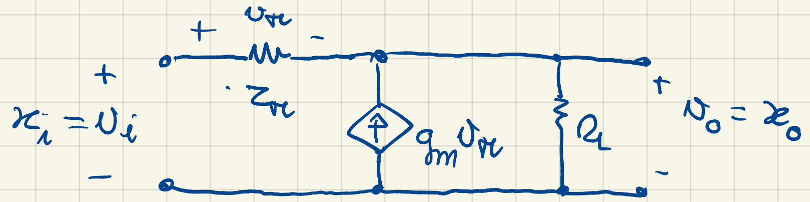
1. CE SMALL SIGNAL MODEL



$$A = \frac{v_o}{v_i} = -g_m R_L$$

IS THIS AMPLIFIER UNILATERAL? YES: NO EFFECT OF v_o OVER v_i

2. CC SMALL SIGNAL MODEL

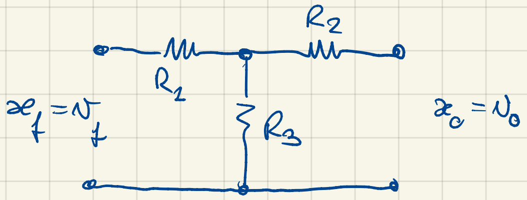


$$A = \frac{v_o}{v_i} \lesssim 1$$

IS THIS AMPLIFIER UNILATERAL? NO: v_o HAS EFFECTS OVER THE INPUT PORT

WHAT ABOUT THE FEEDBACK NETWORK?

AS AN EXAMPLE: RESISTIVE T-NETWORK



β-NETWORKS ARE PASSIVE (MOST OFTEN)

$\Downarrow$

THEY ARE ALWAYS BILATERAL.

IN ADDITION, LOADING EFFECTS ARE ALWAYS FOUND.

ASSUMING THAT A HAS BEEN CALCULATED TAKING INTO ACCOUNT THE LOADING EFFECT AND THAT THE BILATERALITY EFFECTS ARE NEGLIGIBLE, WE CAN APPLY THE USUAL BLOCK DIAGRAM ALGEBRA AND FIND

$$A_F = \frac{x_o}{x_s} = \frac{A}{1 + A\beta}$$

WHERE $A\beta = T$ IS THE LOOP GAIN

THE LOOP GAIN DEFINES THE STABILITY PROPERTIES OF THE CLOSED LOOP AMPLIFIER

THE QUANTITY $|1 + T|$ IS CALLED THE AMOUNT OF FEEDBACK

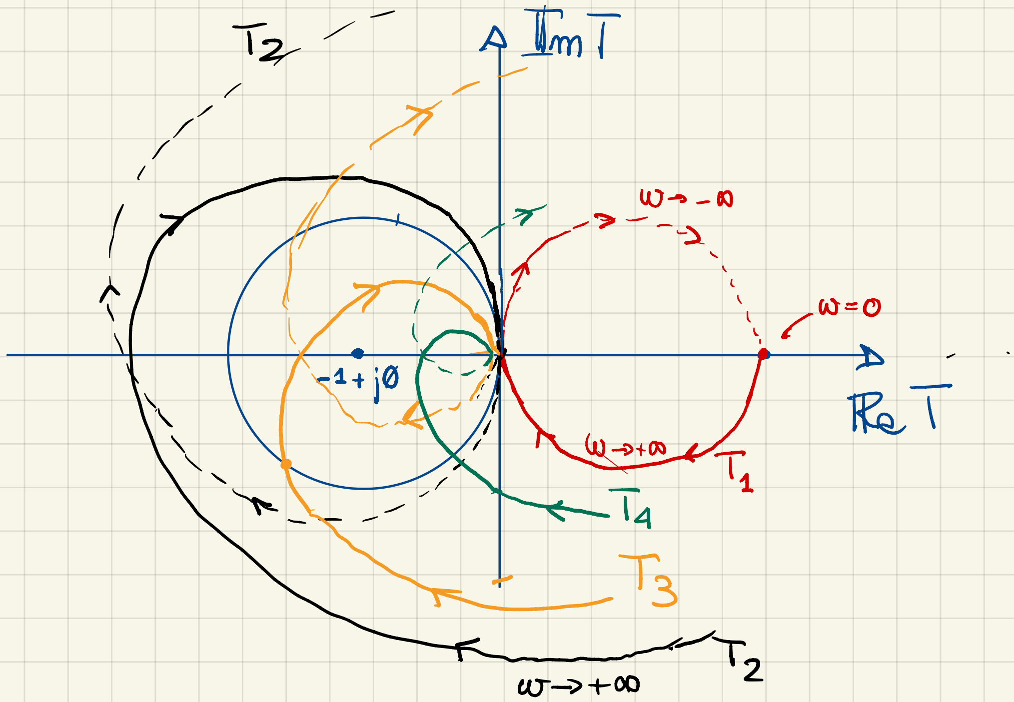
TO TELL POSITIVE FEEDBACK FROM NEGATIVE FEEDBACK WE CHECK THE RELATION BETWEEN A AND A_F

IF $|A_F| > |A|$ WE HAVE POSITIVE FEEDBACK $\iff |1+T| < 1$

IF $|A_F| < |A|$ WE HAVE NEGATIVE FEEDBACK $\iff |1+T| > 1$

STABILITY IS ASSESSED BY THE NYQUIST CRITERION (REVISE)

EXAMPLE



NOTE: WE CAN SAFELY ASSUME BOTH A AND β DO NOT HAVE RHP POLES SO WE CAN TEST THE NUMBER OF CLOSED LOOP RHP POLES COUNTING THE NUMBER OF CLOCKWISE ENCIRCLEMENTS OF $-1 + j0$

T_1 IS A NEGATIVE FEEDBACK STABLE AMPLIFIER. (NO ENCIRCLEMENTS)

T_2 IS A " " " " UNSTABLE " " (2 ENCIRCLEMENTS)

T_3 IS A POSITIVE FEEDBACK UNSTABLE " " (2 ENCIRCLEMENTS)

T_4 IS A " " " " STABLE " " (NO ENCIRCLEMENT)

ALL THAT SAID, WE ARE VERY MUCH INTERESTED IN USING NEGATIVE FEEDBACK, THANKS TO ITS PROPERTIES.

PROPERTIES OF NEGATIVE FEEDBACK

1. DE-SENSITIVENESS

$$\frac{dA_F}{dA} = \frac{1+\beta A - \beta A}{(1+\beta A)^2} = \frac{1}{(1+T)^2} = \frac{1}{A} \cdot A_F \cdot \frac{1}{1+T}$$

$$\frac{dA_F}{A_F} = \frac{dA}{A} \frac{1}{1+T}$$

THE RELATIVE VARIATION OF A_F IS SMALLER THE RELATIVE VARIATION OF A WHEN

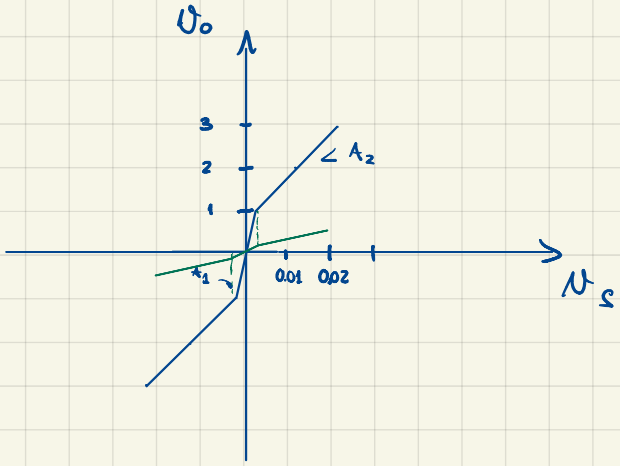
$|1+T|>1 \Rightarrow$ NEGATIVE FEEDBACK MAKES THE AMPLIFIER LESS SENSITIVE TO ANY SORT OF PARAMETRIC VARIATIONS

THE REASON IS THAT

$$A_F = \frac{A}{1+\beta A} \underset{|1+T| \gg 1}{\simeq} \frac{1}{\beta}$$

DOES NOT DEPEND ON THE AMPLIFIER PARAMETERS BUT ONLY ON THE FEEDBACK NETWORK WHICH IS EASIER TO MAKE INSENSITIVE

2. LINEARIZATION



THE NON LINEARITY OF THE TRANSFER-CHARACTERISTIC IS REDUCED IF WE APPLY NEGATIVE FEEDBACK

$A_1 = 1000$ FOR $|v_s| < 0.001$ [p.u.]

$A_2 = 100$ ELSEWHERE

APPLYING NEGATIVE FEEDBACK WITH $\beta = 0.1$ (EXAMPLE) THEN

$$A_{F_1} = \frac{1000}{1+100} \simeq 9.9$$

$$A_{F_2} = \frac{100}{1+10} \simeq 9.1$$

$A_{F_1} \simeq A_{F_2}$ EVEN IF $A_2 \ll A_1$!!

WE HAVE LINEARIZED THE TRANS-CHARACTERISTIC.

3. BANDWIDTH WIDENING

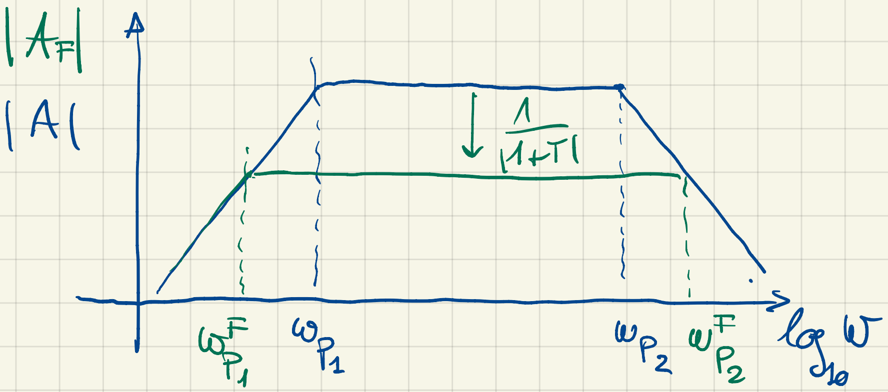
$$A = \frac{A_{MB}}{1 + \frac{s}{\omega_p}} \longrightarrow A_F = \frac{\frac{A_{MB}}{1 + s/\omega_p}}{1 + \frac{\beta A_{MB}}{1 + s/\omega_p}}$$

WE CAN RE-ARRANGE A_F

$$A_F = \frac{A_{MB}}{1 + \beta A_{MB} + s/\omega_p} = \underbrace{\frac{A_{MB}}{1 + \beta A_{MB}}}_{A_{FMB}} \cdot \frac{1}{1 + \frac{s}{\omega_p(1 + \beta A_{MB})}}$$

IF FEEDBACK IS NEGATIVE, THE MID-BAND GAIN DROPS BY A FACTOR $1 + T_{MB}$, BUT THE POLE MOVES FURTHER TO THE RIGHT BY THE SAME FACTOR

EXERCISE: VERIFY THE SAME HAPPENS TO A LOW FREQUENCY POLE



$$\omega^F_{P_2} = \omega_{P_2} |1 + T|$$

$$\omega^F_{P_1} = \frac{\omega_{P_1}}{|1 + T|}$$

THE FEEDBACK AMPLIFIER BANDWIDTH IS WIDENED WITH RESPECT TO THE ORIGINAL ONE!