DECEMBER 2^{ND}, 2022

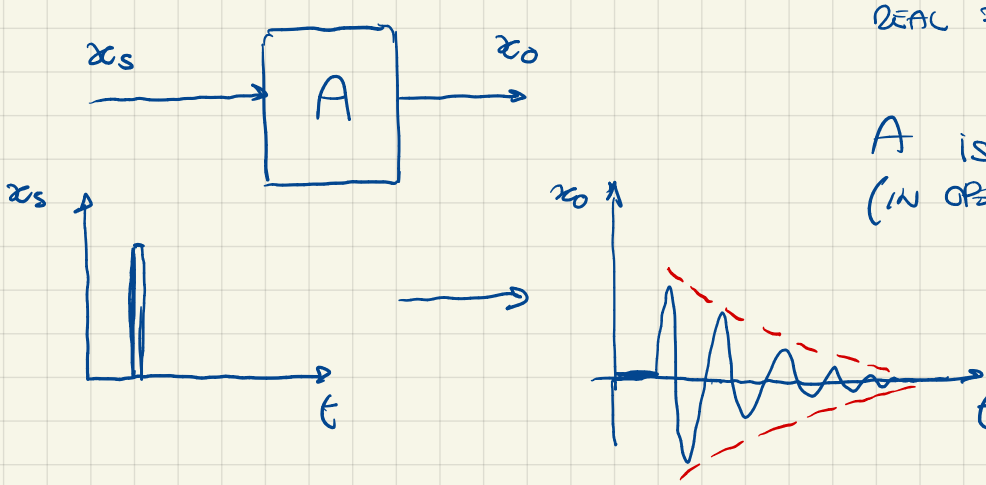
STABILITY AND COMPENSATION OF FEEDBACK AMPLIFIERS

BASIC ASSUMPTIONS

#1 AN ELECTRONIC AMPLIFIER IS INTRINSICALLY STABLE

TEST

I.E. ALL POLES HAVE NEGATIVE REAL PART



A is BIBO STABLE (IN OPEN LOOP CONDITIONS)

#2 FEEDBACK IS APPLIED THROUGH A β-NETWORK WHICH IS, MOST OFTEN, A PASSIVE NETWORK

$\Rightarrow$ β-NETWORK IS ITSELF INTRINSICALLY STABLE

$\Rightarrow$ THE GAIN OF THE β-NETWORK IS LIMITED AT HIGH FREQUENCY

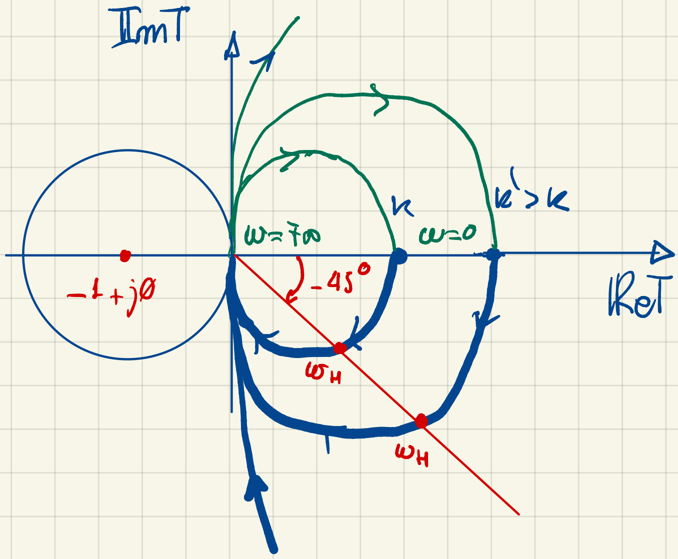
#1 + #2 $\Rightarrow$ WE CAN USE THE SIMPLEST VERSION OF THE NYQUIST STABILITY CRITERION OR EVEN THE BODE STABILITY CRITERION BECAUSE

$T = \beta \cdot A_{OL}$ HAS NO UNSTABLE POLES

IF INSTABILITY OCCURS, UNDER THE ABOVE ASSUMPTIONS, IT IS ONLY DUE TO POOR FEEDBACK DESIGN

THEREFORE STABILITY CAN ALWAYS BE OBTAINED BY PROPERLY DESIGNING THE β-NETWORK. $\Rightarrow$ COMPENSATION IS POSSIBLE.

NYQUIST PLOTS FOR SIMPLE AMPLIFIERS

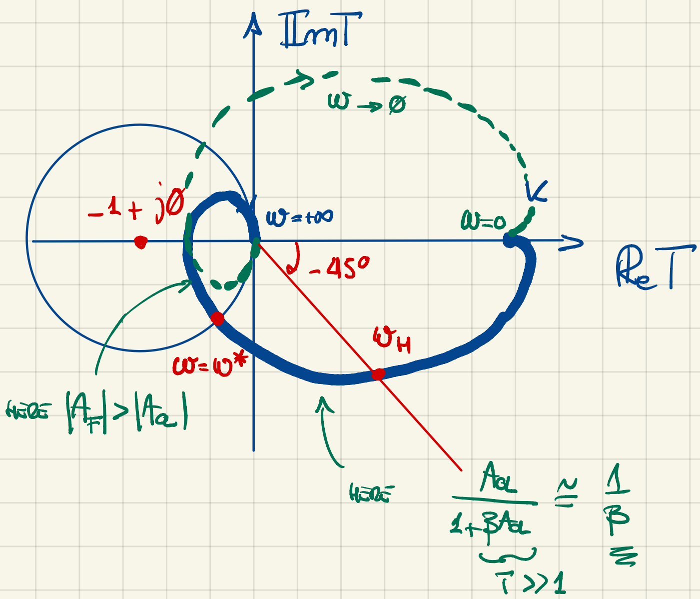


$$T = \frac{k}{1 + \frac{s}{\omega_p}}$$

SINGLE POLE AMPLIFIER

β-NETWORK HAS CONSTANT GAIN β

THIS TYPE OF AMPLIFIER (SINGLE POLE, CONSTANT β) IS ALWAYS STABLE NO MATTER HOW BIG IS β.



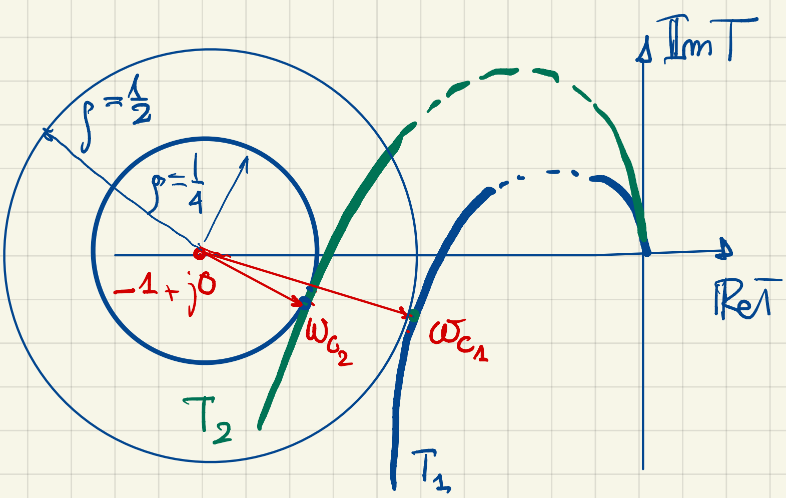
$$T = \frac{k}{\left(1+\frac{s}{\omega_{p_1}}\right)\left(1+\frac{s}{\omega_{p_2}}\right)\left(1+\frac{s}{\omega_{p_3}}\right)}$$

THIS SYSTEM IS STABLE IF k IS SMALL ENOUGH (CAN BE SET WITH β)

AT FREQUENCIES $\omega > \omega^*$ FEEDBACK BECOMES POSITIVE BECAUSE

$$|1+T| < 1 \implies |A_F| = \left|\frac{A_{ol}}{1+T}\right| > |A_{ol}|$$

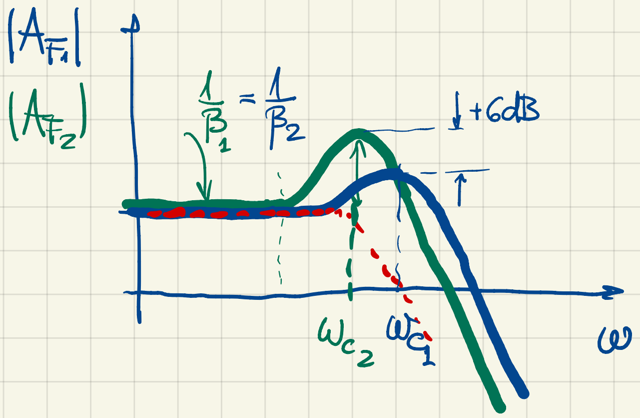
THE IMPACT OF HAVING LOCAL POSITIVE FEEDBACK

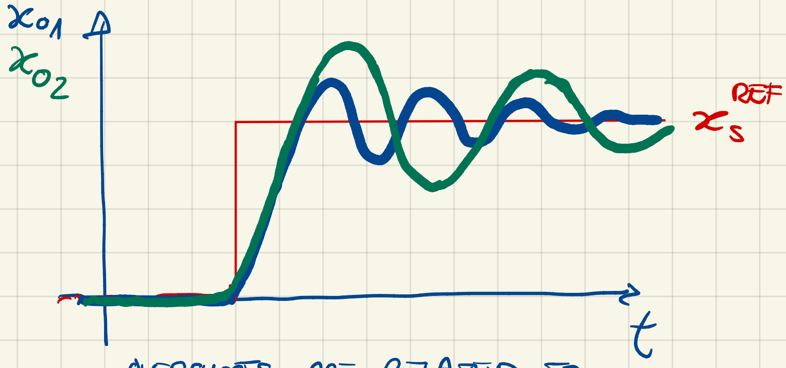


$$|1+T_1(\omega_{C_1})| > |1+T_2(\omega_{C_2})| \implies$$

$$\implies |A_{F_1}(\omega_{C_1})| < |A_{F_2}(\omega_{C_2})|$$

PEAKS OF $A_{F_{1,2}}$ FREQUENCY RESPONSE ARE PLACED AT $\omega_{C_{1,2}}$ MINIMUM DISTANCE POINTS OF THE NYQUIST PLOTS

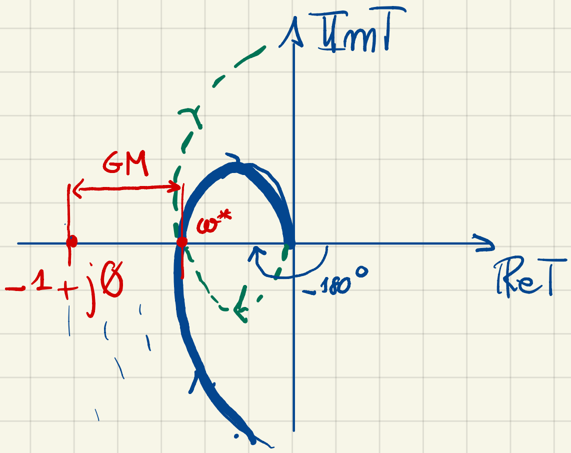




OVERSHOOTS ARE RELATED TO PEAKS OF $|A_F|$

FROM NYQUIST PLOTS, WE CAN ALSO SEE STABILITY MARGINS.

- GAIN MARGIN

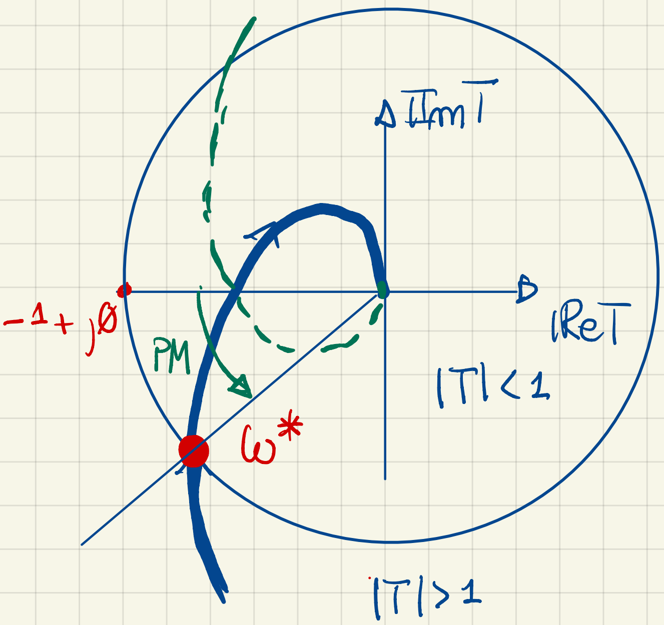


$$GM = 1 - |T(\omega^*)|$$

GM INDICATES HOW MUCH T CAN BE INFLATED BEFORE BECOMING UNSTABLE

ω^* IS THE FREQUENCY WHERE $\angle T$ IS EQUAL TO $-\pi$.

- PHASE MARGIN



$$PM = \pi + \angle T(\omega^*)$$

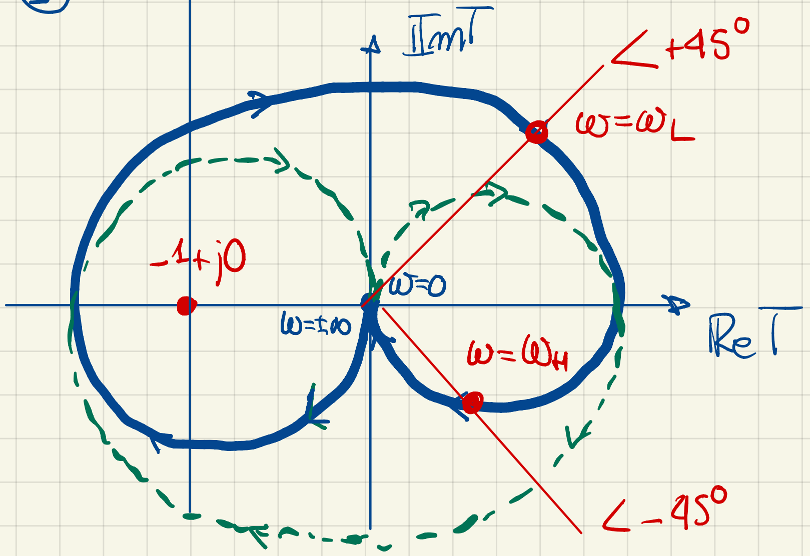
PM INDICATES HOW MUCH WE CAN ROTATE THE PHASE OF T AT EACH FREQUENCY BEFORE THE SYSTEM BECOMES UNSTABLE

$\omega^* = \omega_{CR}$ FREQUENCY WHERE $|T| = 1$.

IF PM IS <0 OR GM IS <0 THE CLOSED LOOP SYSTEM WILL BE UNSTABLE

THERE CAN BE TWO TYPES OF INSTABILITY

1



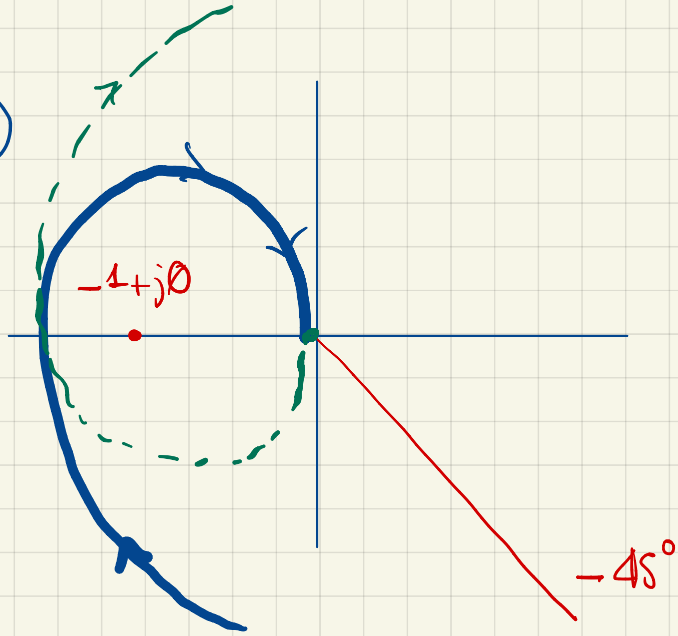
WE HAVE TWO ENCIRCLEMENTS → TWO RHP POLES LOCATED AT FREQUENCIES BELOW ω_L

THIS IS A LOW FREQUENCY TYPE OF INSTABILITY.

IT IS TYPICALLY DUE TO THE POOR DESIGN OF COUPLING CAPACITORS (TOO SMALL)

"HICCUP" INSTABILITY

2



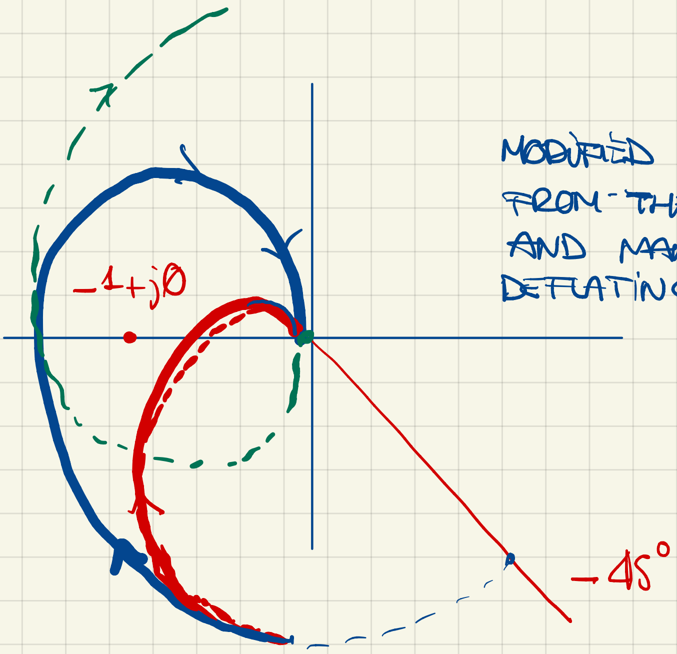
THE INSTABILITY IS TAKING PLACE ABOVE ω_H SO AT HIGH FREQUENCY

THIS TYPE OF INSTABILITY DEPENDS ON THE PARASITIC CAPACITORS OF TRANSISTORS (C_μ, C_π, C_{GD} ...) AND CAN BE CORRECTED MODIFYING THE β-NETWORK.

⇓

COMPENSATION

FOR EXAMPLE IF WE MODIFY β (WE MAKE IT FREQUENCY DEPENDENT) WE CAN STABILIZE THE AMPLIFIER



MODIFIED β-NETWORK BECOMES EFFECTIVE (DIFFERS FROM THE ORIGINAL ONE) ONLY AT $\omega \gg \omega_H$ AND MAKES THE AMPLIFIER STABLE BY DEFLATING T AT HIGH FREQUENCY.

$T = \beta A_d$ BEFORE COMPENSATION

$T' = \beta'(s) \cdot A_d$ AFTER COMPENSATION