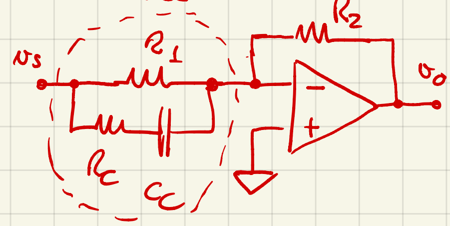
FOR $|T| \gg 1$

$$A_v = \frac{v_o}{v_s} \simeq -\underbrace{\frac{R_2 /\!/ Z_c}{R_1 + R_2 /\!/ Z_c}}_{k_s} \cdot \underbrace{\frac{R_2 + R_1 /\!/ Z_c}{R_1 /\!/ Z_c}}_{1/\beta} = -\frac{R_2}{R_1}$$

PROVE AS EXERCISE

IMPORTANT: THIS DOES NOT HAPPEN IF Z_c IS CONNECTED IN PARALLEL TO R_1 LIKE



DO NOT USE THIS CONFIGURATION !!

HINT:

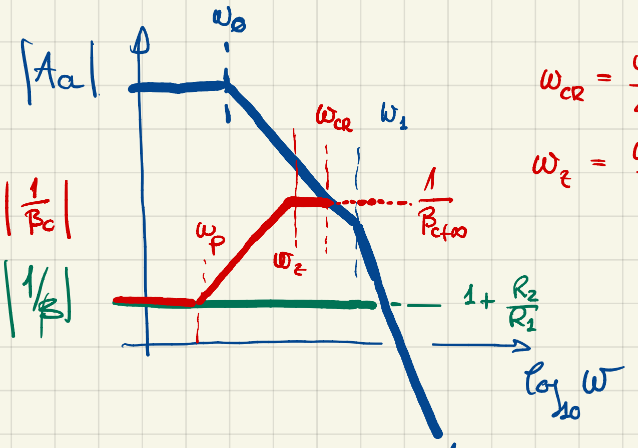
$$\frac{R_2 /\!/ Z_c}{R_1 + R_2 /\!/ Z_c} = R_1 /\!/ R_2 /\!/ Z_c \cdot \frac{1}{R_1}$$

$$\frac{R_2 + R_1 /\!/ Z_c}{R_1 /\!/ Z_c} = \frac{R_2}{R_2 /\!/ R_1 /\!/ Z_c}$$

DESIGN OF COMPENSATION NETWORK

TARGET $\Delta PM = +60^\circ$

THIS MEANS WE ARE DESIGNING β_c SO THAT:



$$\left.\begin{aligned} \omega_{cr} &= \frac{\omega_1}{4} \\ \omega_z &= \frac{\omega_{cr}}{4} \end{aligned}\right\} \Rightarrow \omega_z = \frac{\omega_1}{16}$$

CONDITION TO GET $\Delta PM = +60^\circ$ WITH A ZERO (ω_z) POLE (ω_1) COMBINATION AROUND ω_{cr}

TO FIND ω_p WE CAN FIND $\frac{1}{\beta_{c\infty}}$

$$A_{ol\phi} \cdot \omega_0 = \frac{1}{\beta_{c\infty}} \cdot \frac{\omega_1}{4} \Rightarrow \frac{1}{\beta_{c\infty}} = \frac{4 A_{ol\phi} \omega_0}{\omega_1}$$

THAT IS KNOWN FROM OPAMP CHARACTERISTICS

FROM THIS WE FIND ω_p IMPOSING

$$\frac{1}{\omega_p} \frac{1}{\beta_{c\phi}} = \frac{1}{\beta_\phi} \cdot \frac{1}{\omega_p} = \frac{1}{\beta_{c\infty}} \cdot \frac{16}{\omega_1} \Rightarrow \omega_p = \frac{\beta_{c\infty}\, \omega_1}{16 \beta_{c\phi}} = \frac{\omega_1^2}{64 A_{ol\phi} \omega_0 \beta_{c\phi}}$$

IN THIS CIRCUIT

$$\frac{1}{\beta_c}(s) = 1 + \frac{R_2}{R_1 /\!/ Z_c} = 1 + R_2 \cdot \left(\frac{1}{R_1} + \frac{1}{R_c + \frac{1}{sC_c}}\right) = 1 + \frac{R_2}{R_1} + \frac{sR_2C_c}{1 + sR_cC_c}$$

$$= \frac{(1 + sC_cR_c)(R_1 + R_2) + sR_1R_2C_c}{R_1(1 + sC_cR_c)} = \frac{R_1 + R_2}{R_1} \cdot \frac{1 + sC_c(R_c + R_1 /\!/ R_2)}{1 + sR_cC_c}.$$

FROM WHICH WE SEE THAT:

$$\frac{1}{\beta_{c\varnothing}} = 1 + \frac{R_2}{R_1}$$ AS WE EXPECTED IT IS EQUAL TO $1/\beta_{\varnothing}$

$$\omega_z = 1/R_cC_c$$ → FROM HERE WE GET $C_c = \frac{1}{R_c\omega_z}$

$$\omega_p = 1/C_c\left(R_c + R_1 /\!/ R_2\right)$$ → FROM WHICH, USING THIS, WE FIND

$$\omega_p = \frac{R_c \cdot \omega_z}{R_c + R_1 /\!/ R_2} = \frac{\omega_z}{1 + \frac{R_1 /\!/ R_2}{R_c}} \iff$$

FROM WHICH, FINALLY, WE CAN FIND

$$\boxed{R_c = \frac{R_1 /\!/ R_2}{\frac{\omega_z}{\omega_p} - 1} \qquad C_c = \frac{1}{R_c\omega_z}}$$

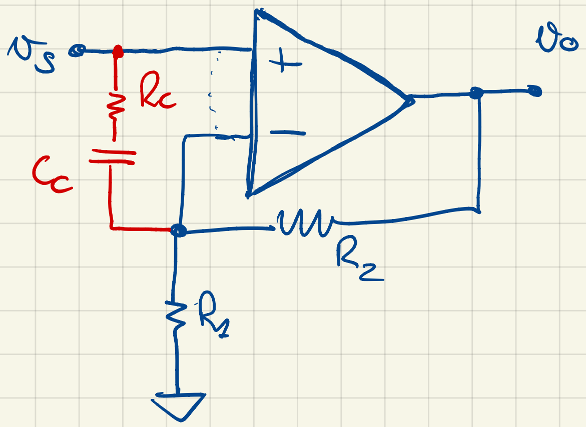
FASTER PROCEDURE

FROM THE CIRCUIT WE SEE THAT $\frac{1}{\beta_{c\infty}} = 1 + \frac{R_2}{R_1 /\!/ R_c} = \underbrace{4 \cdot A_{o\varnothing}\frac{\omega_0}{\omega_1}}_{\text{KNOWN}}$

FROM HERE WE CAN DIRECTLY FIND R_c

THEN, C_c IS FOUND AS $\frac{1}{R_c\omega_z}$

IN THE NON-INVERTING CASE THE NOISE GAIN COMPENSATION LOOKS LIKE THIS



WHEN $|T| \gg 1$ $A_0 = \frac{v_o}{v_s} \simeq 1 + \frac{R_2}{R_1}$

BUT THE AMPLIFIER WILL BE COMPENSATED.

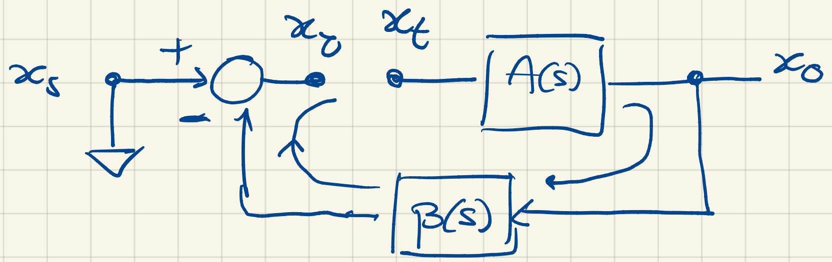
THE DESIGN PROCEDURE FOR R_c AND C_c IS THE SAME AS IN THE INVERTING CONFIGURATION CASE.

VERIFY THIS AS AN EXERCISE!

OSCILLATORS

- NON SINUSOIDAL (SCHMITT TRIGGER)
- SINUSOIDAL

WE CONSIDER THE LATTER CASE. ALL BEGINS WITH A FEEDBACK AMPLIFIER



$$\frac{x_o}{x_s} = \frac{A}{1+T}$$

$$\frac{X_R}{X_T}(s) = -A(s)\cdot\beta(s) = -T(s)$$

N.B. $\angle \frac{X_R}{X_T} = \angle T + \pi$

DUE TO THE "$-$" SIGN AT THE SUMMING NODE

IN SINUSOIDAL OSCILLATORS, WE INTENTIONALLY CREATE THE CONDITIONS TO HAVE THE CIRCUIT OSCILLATE AT SOME FREQUENCY ω_0

THESE CONDITIONS ARE NAMED **BARKHAUSEN** CONDITIONS

$$\begin{cases} |T(j\omega_0)| = 1 \\ \angle T(j\omega_0) = \pm(2m+1)\pi \qquad m \in \mathbb{N} \end{cases}$$

THE SIMPLEST WAY TO SATISFY BARKHAUSEN CONDITIONS IS TO HAVE

$$T = -1 \quad @\ \omega = \omega_0 \quad \Rightarrow \quad \frac{X_R}{X_T}(j\omega_0) = +1 \ !!$$

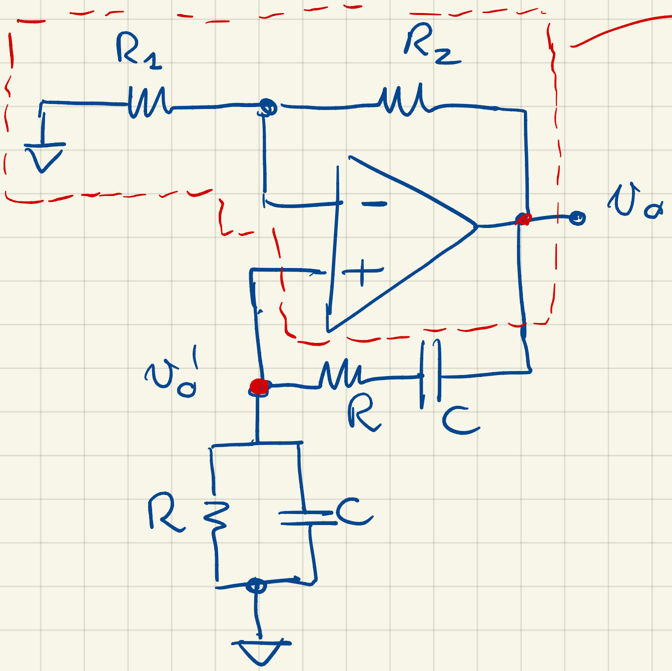
THIS HAPPENS ANY TIME $1+T$ INCLUDES A TERM AS

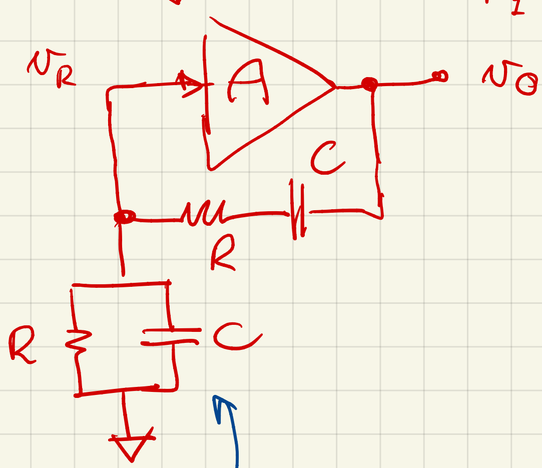
$(s^2+\omega_0^2)$ WHICH IS $= \emptyset$ @ $\omega = \omega_0$

◊ A TYPICAL OSCILLATOR CIRCUIT IS THE ONE CALLED THE

WIEN BRIDGE

OSCILLATOR THAT IS BASED ON A SIMPLE OPAMP CONFIGURATION.





LET'S FIND T(s) FOR THIS AMPLIFIER

$$T(s) = A \cdot \frac{\frac{R}{1+sRC}}{\frac{R}{1+sRC} + R + \frac{1}{sC}} = A \cdot \frac{R}{R + R(1+sRC) + \frac{1+sRC}{sC}} =$$

$$= A \cdot \frac{sCR}{sCR\left(2 + sCR\right) + 1 + sCR} = A \cdot \frac{sCR}{1 + 3sCR + s^2(CR)^2}$$

LET'S CONSIDER $T(j\omega_0)$ WHERE $\omega_0 = \frac{1}{RC}$

$$\begin{cases} |T(j\omega_0)| = A \cdot \left| \frac{j}{\cancel{1} + 3j - \cancel{1}} \right| = \frac{A}{3} \\ \angle T(j\omega_0) = 0^\circ \end{cases}$$

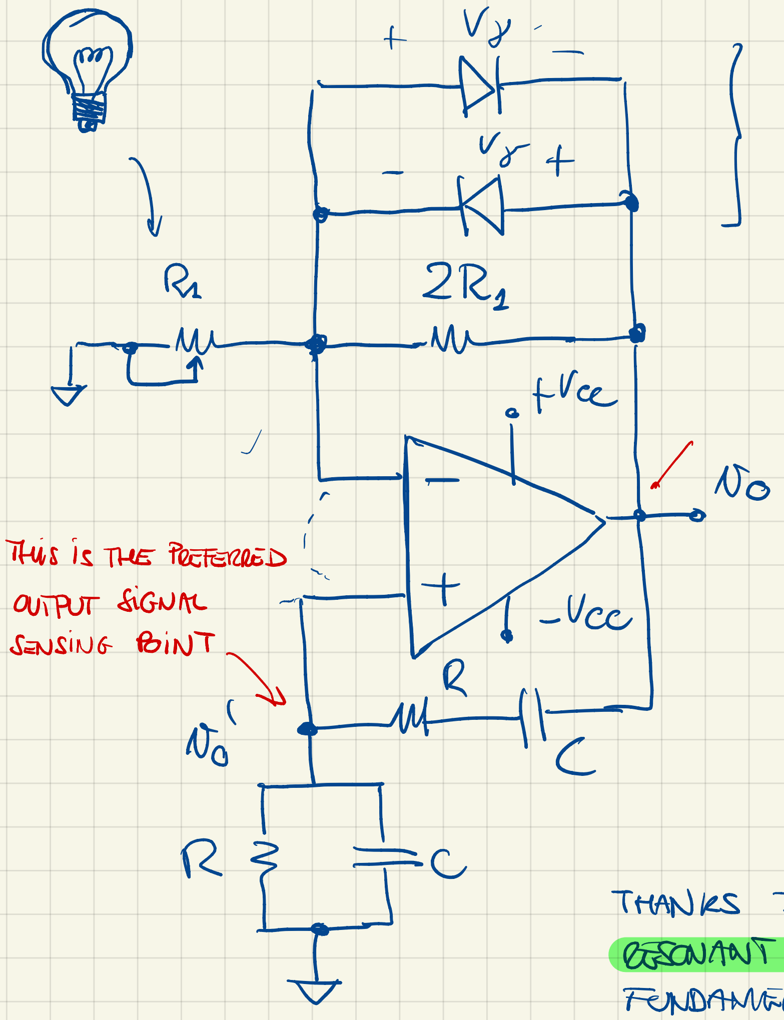
N.B. IN THIS CASE $\frac{X_R}{X_T}(s) = T(s)$ BECAUSE THERE IS NO SUMMING NODE AND NO SIGN INVERSION.

WE CAN SATISFY BARKHAUSEN CONDITIONS BY MAKING

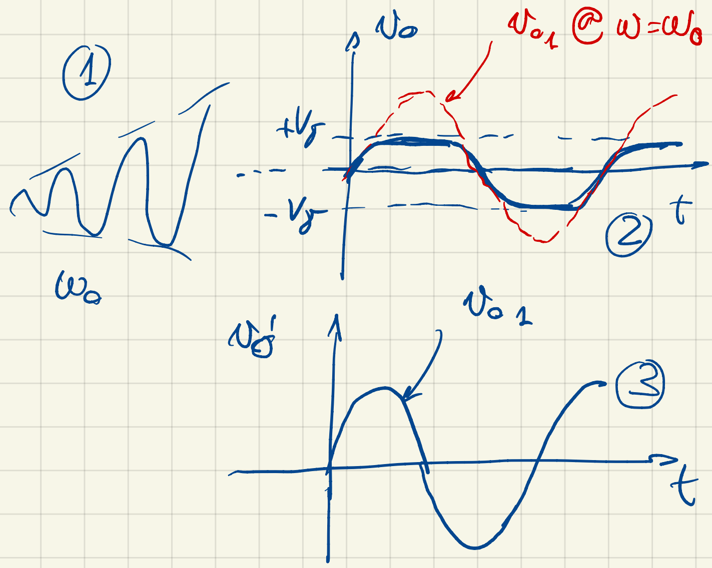
$$A = 3 \quad \Rightarrow \quad 1 + \frac{R_2}{R_1} = 3 \quad \Rightarrow \quad R_2 = 2R_1$$

IN PRACTICE WE CHOOSE $R_2 > 2R_1$ TO START THE OSCILLATION RAPIDLY.

AND THEN WE PREVENT SATURATION BY ACTIVELY LIMITING THE OSCILLATION AMPLITUDE. A SIMPLE IMPLEMENTATION IS:



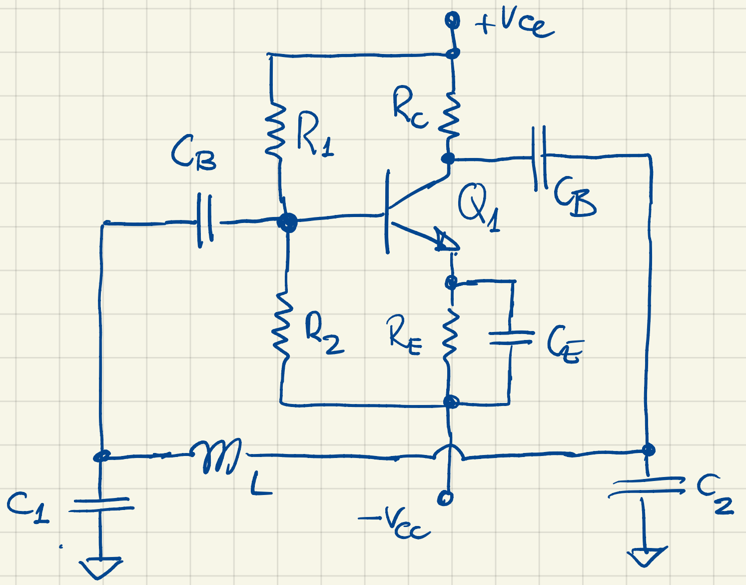
NON LINEAR NETWORK REDUCES THE CIRCUIT GAIN ANY TIME $v_o(t)$ GETS CLOSE TO $\pm V_\gamma$ (THE DIODE FORWARD VOLTAGE DROP)



THANKS TO THE SELECTIVITY OF THE RESONANT β-NETWORK $v_o' \simeq v_{o1}$ THE FUNDAMENTAL HARMONIC COMPONENT OF v_o

ANOTHER WAY IS TO MAKE R_2 A PTC RESISTOR. A SIMPLE EXAMPLE OF PTC RESISTOR IS A LIGHT BULB. REPLACING R_1 WITH A PTC AGAIN STABILIZES THE AMPLITUDE

◊ A SINUSOIDAL OSCILLATOR CAN BE MADE ALSO USING A SIMPLE C-E (OR C-S) AMPLIFIER.

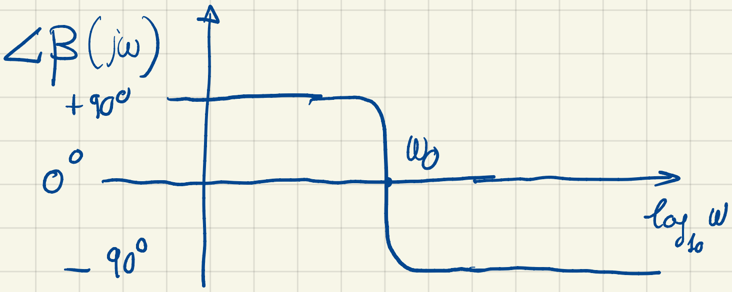


COLPITTS OSCILLATOR
(COMMON EMITTER BASED)

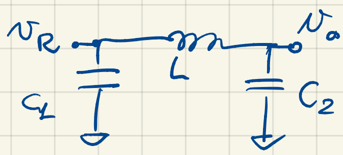
Hyp: @ $\omega = \omega_0$

① C_C AND C_B ARE PRACTICALLY SHORTED

② $\omega_0 \ll \omega_T$ SO THAT C_{π} AND C_{μ} ARE PRACTICALLY OPEN



THE β-NETWORK



IS "SELECTIVE", ITS PHASE IS EQUAL TO 0° AT $\omega = \omega_0$ BUT PHASE VARIATION IS VERY "FAST". A SIGNAL WITH FREQUENCY DIFFERENT FROM ω_0 (EVEN BY A LITTLE AMOUNT) WILL NOT MEET BARKHAUSEN CONDITIONS AND WILL NOT PROPAGATE AROUND THE LOOP

SELECTIVITY $\Rightarrow$ THE OSCILLATION FREQUENCY WILL BE VERY STABLE