ESERCITATORE

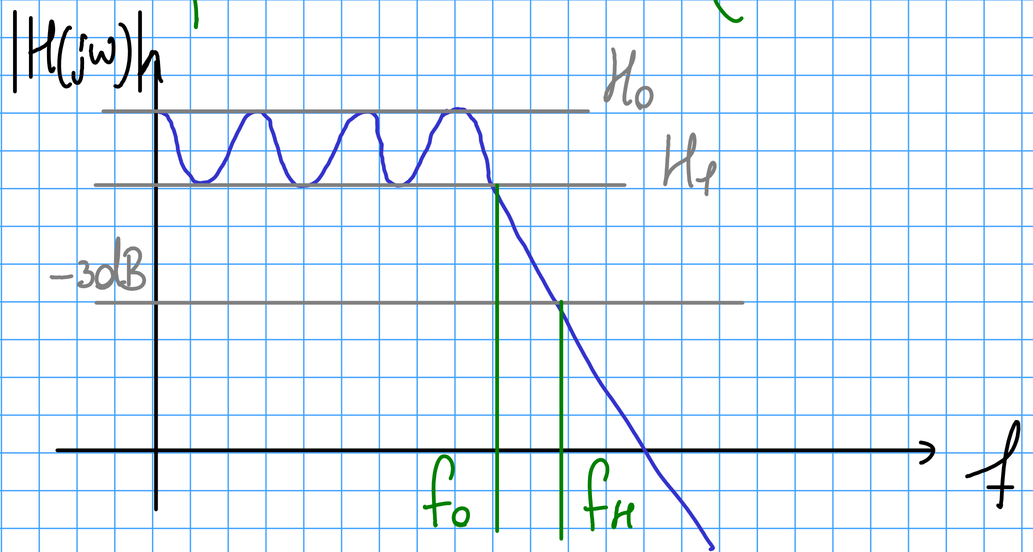
20 DIC

Filtri Chebyshev ellittici

Butterworth → risposta piatta in banda passante

Chebishev → oscillazione in banda ma riduco almeno di un grado la complessità rispetto a butterworth (minor costo)

$$|H(j\omega_0)|^2 = \frac{H_0^2}{1 + \varepsilon^2 C_n^2\left(\frac{\omega}{\omega_c}\right)}$$



dove $C_n\left(\frac{\omega}{\omega_c}\right) = \begin{cases} \cos\left[n \cos^{-1}\left(\frac{\omega}{\omega_c}\right)\right] & 0 \leq \frac{\omega}{\omega_c} \leq 1 \\ \cosh\left[n \cosh^{-1}\left(\frac{\omega}{\omega_c}\right)\right] & \frac{\omega}{\omega_c} > 1 \end{cases}$

$$|H_1(f=f_c)|^2 = \frac{H_0^2}{1+S}$$ banda di ondulazione

coeff. su tabelle $\longrightarrow$ tabulati per grado al variare dell'ondulazione

$$\gamma_{dB} = |H_0|_{dB} - |H_1|_{dB} = 20\log\frac{H_0}{H_1}$$

$$\boxed{10^{\frac{\gamma}{10}} - 1 = \varepsilon^2}$$

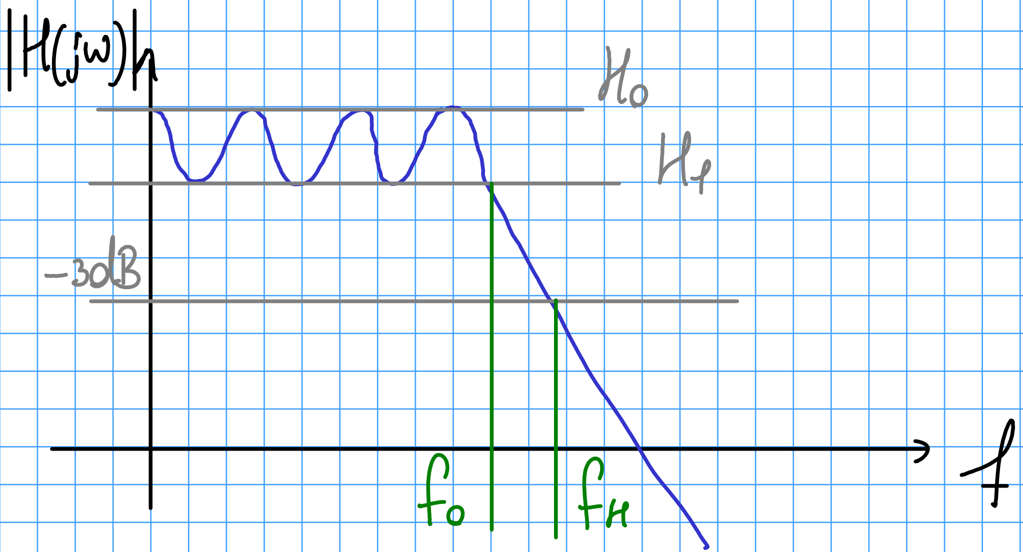
con $\gamma = 0{,}5\,dB \longrightarrow \varepsilon = 0{,}3493$

con $\gamma = 1\,dB \longrightarrow \varepsilon = 0{,}5089$

banda

$$\boxed{f_H = f_c \cosh\left[\frac{1}{n}\cosh^{-1}(1/\varepsilon)\right]}$$

in generale $f_c \approx f_H$



exercizio

40 dB su $\frac{\omega}{\omega_c} = 2$

se non ho specifiche stringenti uso chebishev che consente un ordine inferiore

confronto butterworth / chebishev (con $\gamma = 1$ dB)

CHEBISHEV

$$\frac{|H(j\omega)|^2}{|H_0|^2} = \frac{1}{1+\varepsilon^2 C_n^2\left(\frac{\omega}{\omega_c}\right)} = \frac{1}{1+\varepsilon^2 C_n^2\, 2} = 10^{-4}$$

$$1+\varepsilon^2 C_n^2(2) = 10^{+4} \longrightarrow C_n^2(2) = \frac{10^4}{(0{,}5089)^2} = 38{,}613 \cdot 10^3$$

$$\gamma = 1\,dB \longrightarrow \varepsilon = 0{,}5089$$

$$\longrightarrow C_n(2) = 196{,}49$$

$$C_n(2) = \cosh\left[n \cosh^{-1}(2)\right] \longrightarrow n = 4{,}53 \longrightarrow n = 5$$

ordine polinomio 5

$$f_H = 1{,}034 f_c \approx f_c$$

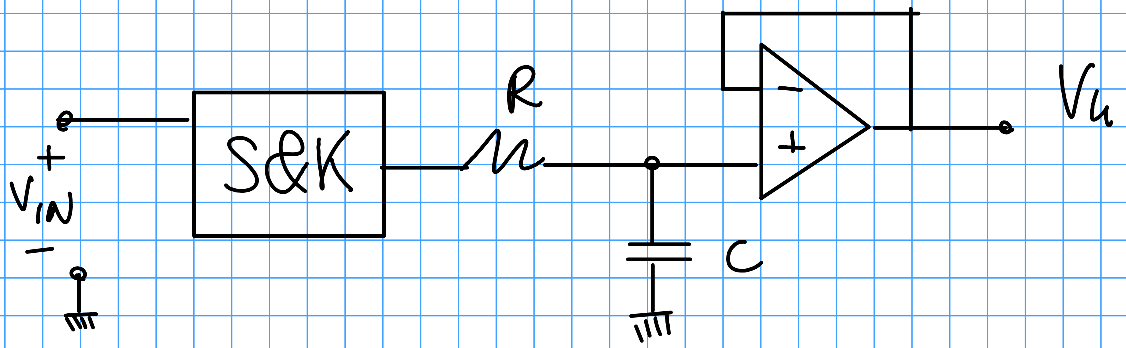
vediamo butterworth

$$\frac{|H(j\omega)|}{|H_0|} = \frac{1}{\sqrt{\left(\frac{\omega}{\omega_c}\right)^{2n}+1}} \longrightarrow \frac{1}{\sqrt{\left(\frac{\omega}{\omega_c}\right)^{2n}+1}} = 10^{-4}$$

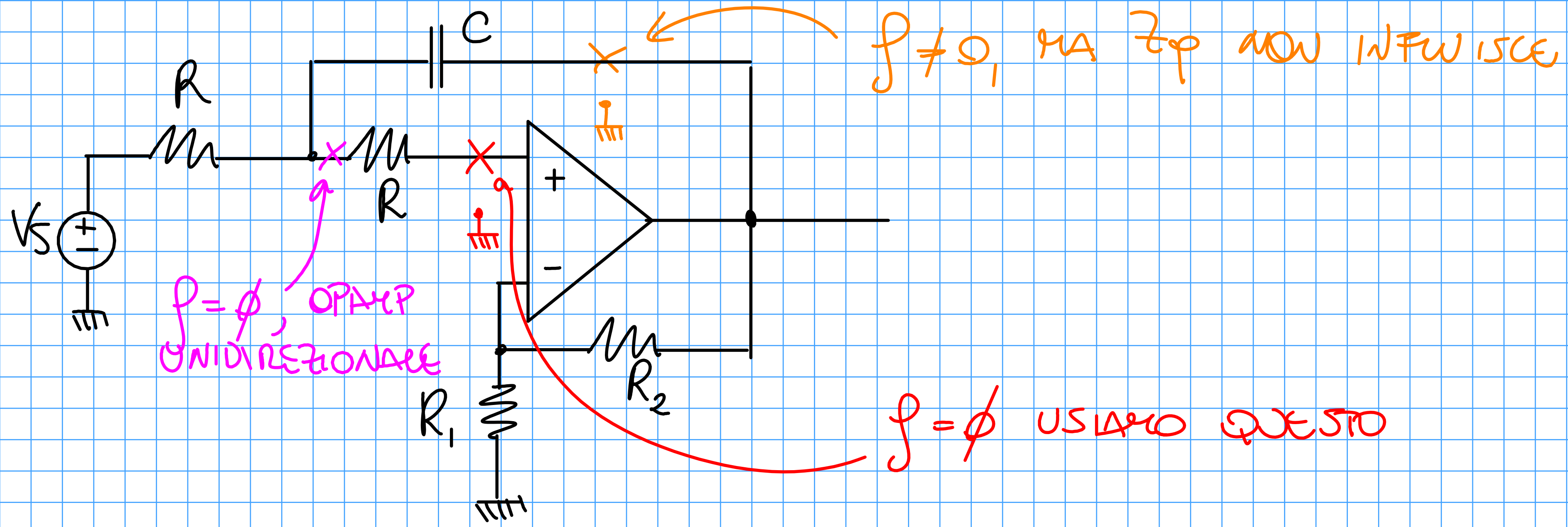
$$\left(\frac{\omega}{\omega_c}\right)^{2n} = 10^4 - 1 \longrightarrow 4^n = 10^4 \longrightarrow \underline{\underline{n = 7}}$$

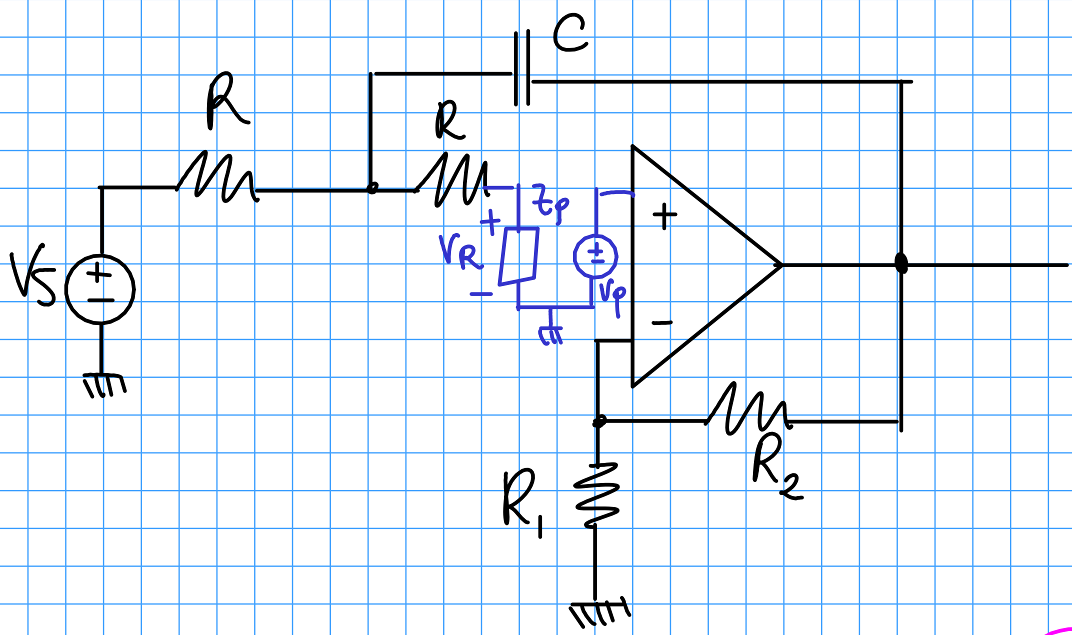
con butterworth → 7° grado!

supponiamo $n=3$, come lo realizzo?



cella di Sallen & Key





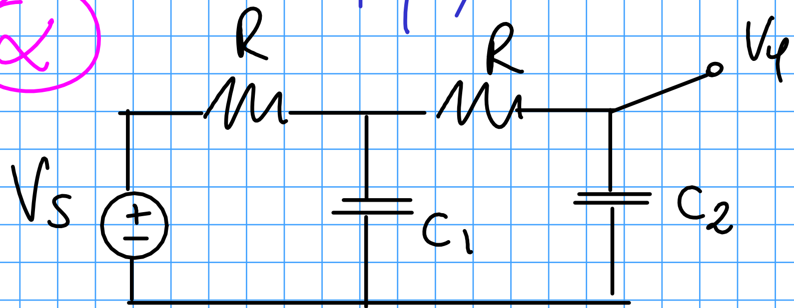
$$\rho = \emptyset, \quad \gamma = \left.\frac{V_u}{V_S}\right|_{V_\varphi=\emptyset} = \emptyset$$

$$A_f = \frac{\alpha A}{1-\beta A}$$

$$A = \left.\frac{V_u}{V_\varphi}\right|_{V_s=\emptyset} = 1 + \frac{R_2}{R_1}$$

$$\alpha = \left.\frac{V_R}{V_s}\right|_{V_\varphi=\emptyset}$$

α



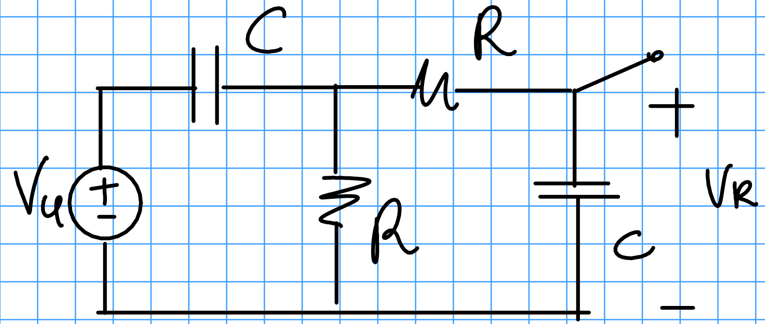
$$\alpha(f) = \frac{\alpha_0 = 1}{a_2 s^2 + a_1 s + 1}$$

$$a_1 = R^0_{11} C_1 + R^0_{22} C_2 = RC_1 + 2RC_2 = 3RC$$

$$a_2 = C_1 C_2 R^0_{11} R^1_{22} = C_1 C_2 R R = R^2 C^2$$

$$\alpha = \frac{1}{R^2C^2s^2 + 3RCs + 1}$$

β

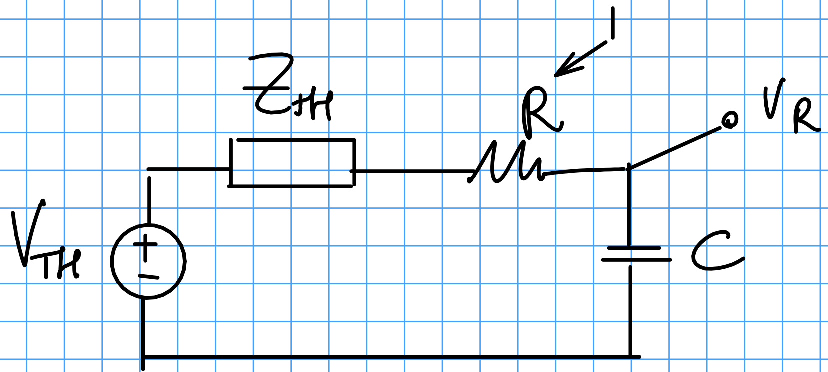


$$\beta = \frac{Ks}{R^2C^2s^2 + 3RCs + 1}$$

COME α

ZERO NELL'ORIGINE

CALCOLO ZERO $\longrightarrow$ CHIUDO C_1



$$V_{TH} = V_u \frac{R}{R + \frac{1}{Cs}}$$

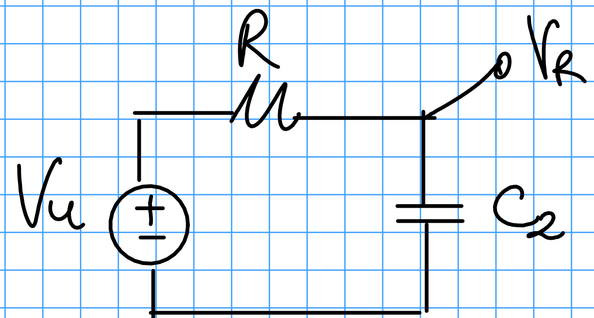
$$Z_{TH} = \frac{R}{RCs + 1}$$

SE $s \to +\infty$

$V_{TH} \to V_u$

$Z_{TH} \to \emptyset$

AL LIMITE VERO CIRCUITO SEMPLIFICATO



V_R CON $s \to +\infty$

$$\left.\frac{V_R}{V_u}\right|_{V_S = \emptyset} = \frac{\frac{1}{Cs}}{\frac{1}{Cs} + R}$$

$$\beta_\infty = \frac{1}{RCs + 1}$$

acvin.it

$$\beta = \frac{Ks}{R^2C^2s^2 + 3RCs + 1} \qquad \beta_\infty = \frac{1}{RCs}$$

$$\frac{1}{RCs} = \frac{K}{R^2C^2s} \implies K = RC$$

$$\beta = \frac{RC}{R^2C^2s^2 + 3RCs + 1}$$

$$A_f = \frac{\alpha A}{1-\beta A} = \frac{A_0}{R^2C^2s^2 + 3RCs + 1 - A_0RCs}$$

$$A_f = \frac{A_0}{R^2C^2s^2 + RCs(3-A_0) + 1}$$

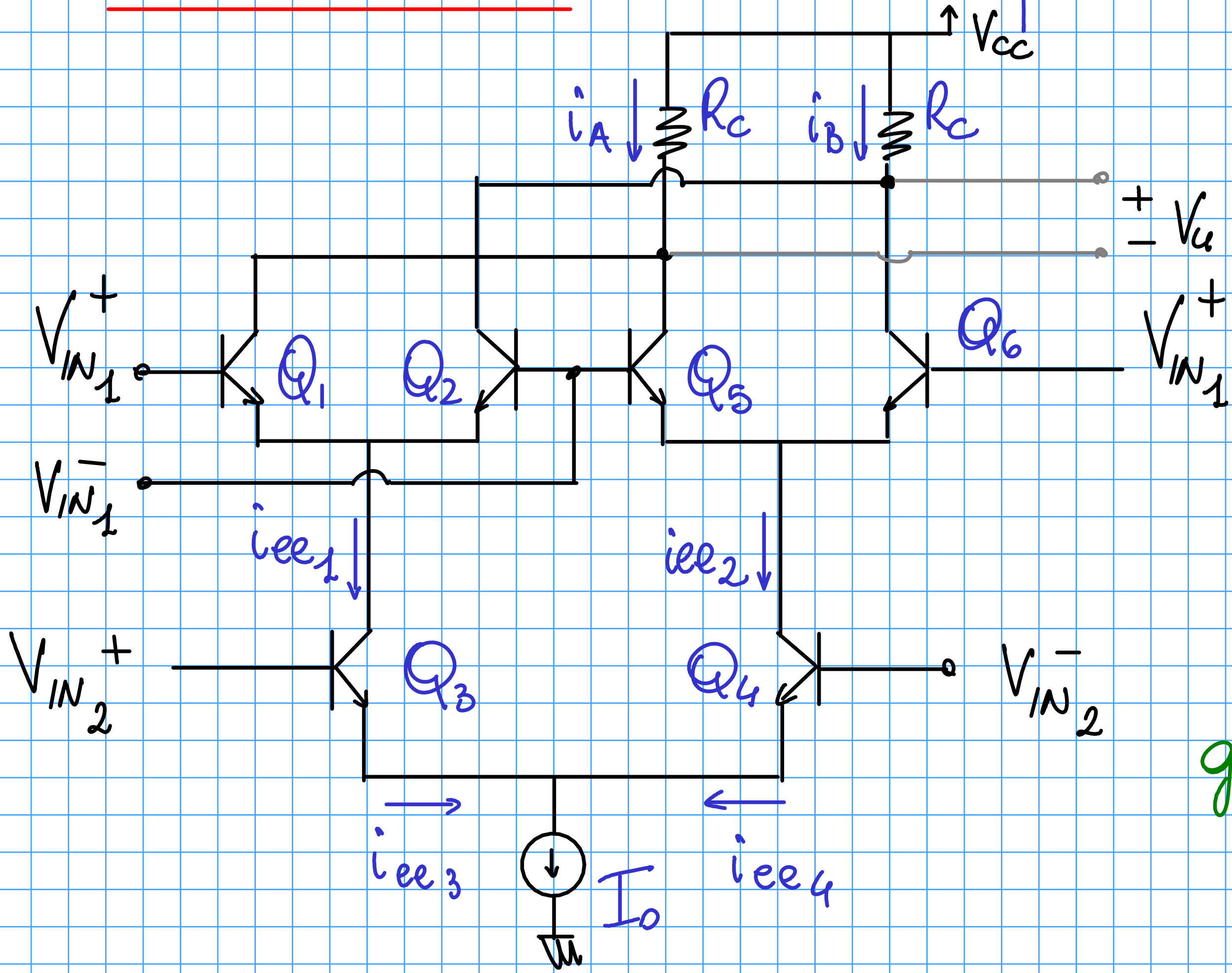
GRADO 2 $\longrightarrow$ REGOLA <u>NEWTON</u> $\longrightarrow$ POLI A PARTE REALE POSITIVA QUANTE SONO LE VARIAZIONI DI SEGNO

GRADO SUP $\longrightarrow$ " <u>ROUTH</u>

$\longrightarrow$ STABILE $\longrightarrow$ $3 - A_0 > 0 \implies \underline{A_0 < 3}$

$\longrightarrow$ SE VOGLIO A MAGGIORE $\longrightarrow$ USO ALTRO AMP. IN CASCATA

Cella di Gilbert $\longrightarrow$ moltiplicazioni a 4 quadranti



polarizzazione

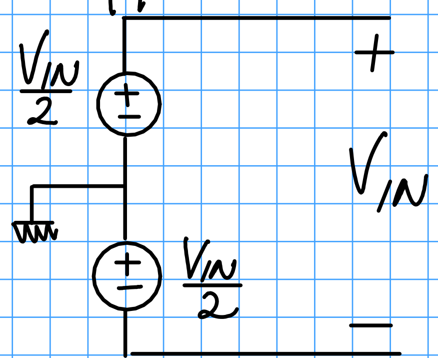
$$\boxed{I_{EE1} = I_{EE2} = \frac{I_o}{2}}$$

valore totale (riposo + variazione)

$$\begin{cases} i_{EE1} = g_{m3} \dfrac{V_{IN2}}{2} \\ i_{EE2} = -g_{m4} \dfrac{V_{IN2}}{2} \end{cases}$$

$$g_{m3} = g_{m4} = \frac{I_o}{2V_T}$$

sviluppo:

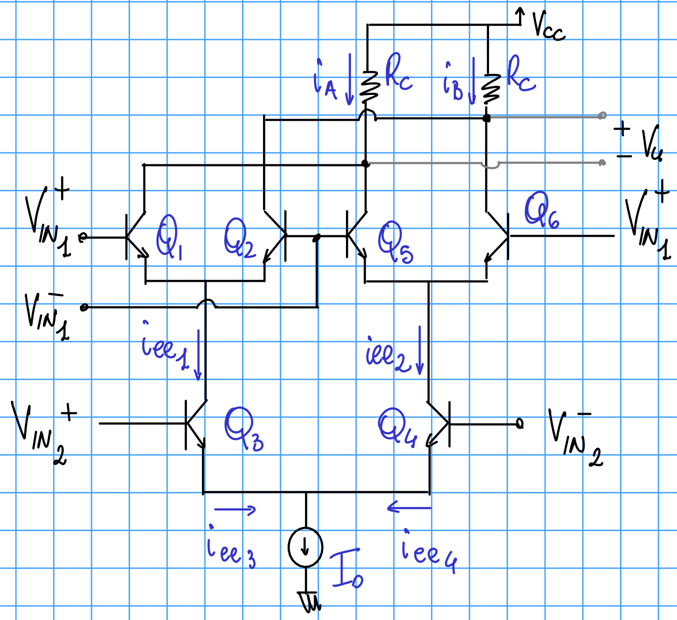


sostituisco $g_m \longrightarrow$

$$\begin{cases} i_{EE1} = +\dfrac{I_o}{2V_T} \dfrac{V_{IN2}}{2} \\ i_{EE2} = -\dfrac{I_o}{2V_T} \dfrac{V_{IN2}}{2} \end{cases}$$

$$g_m = \frac{I_C}{V_T}$$

$$\begin{cases} i_A = i_{C1} + i_{C5} \\ i_B = i_{C6} + i_{C2} \end{cases}$$



$$i_{C1} = \frac{i_{EE1}}{2} + g_{m1}\frac{V_{IN1}}{2}$$

$$i_{C5} = \frac{i_{EE2}}{2} - g_{m5}\frac{V_{IN1}}{2}$$

$$i_{C6} = \frac{i_{EE2}}{2} + g_{m6}\frac{V_{IN1}}{2}$$

$$i_{C2} = \frac{i_{EE1}}{2} - g_{m2}\frac{V_{IN1}}{2}$$

con $g_{m1} = g_{m2}$, $g_{m5} = g_{m6}$

riscrivo i_A e i_B con le relazioni trovate

$$\begin{cases} i_A = \frac{i_{EE1}}{2} + g_{m1}\frac{V_{IN1}}{2} + \frac{i_{EE2}}{2} - g_{m5}\frac{V_{IN1}}{2} \\ i_B = \frac{i_{EE2}}{2} + g_{m6}\frac{V_{IN1}}{2} + \frac{i_{EE1}}{2} - g_{m2}\frac{V_{IN1}}{2} \end{cases}$$

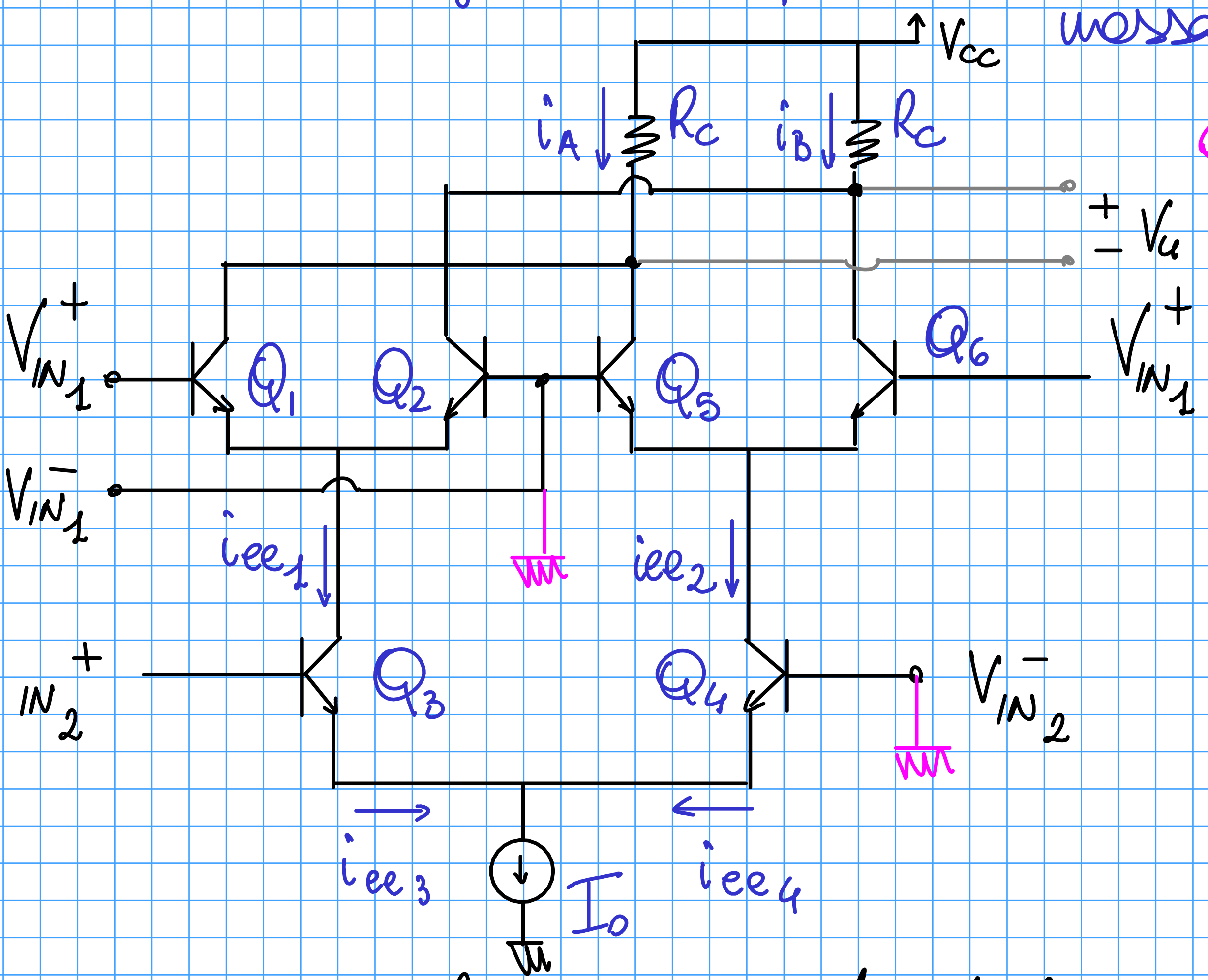
calcolo uscita

$$V_u = (V_{CC} - R_C i_B) - (V_{CC} - R_C i_A) = R_C(i_A - i_B) = R_C(g_{m1} - g_{m6})V_{IN} =$$

$$= R_C\left(\frac{i_{EE1}}{2V_T} - \frac{i_{EE2}}{2V_T}\right)V_{IN} = \frac{R_C}{2V_T}\left(\frac{I_o}{2V_T}\right)V_{IN_1}V_{IN_2} \longrightarrow \boxed{V_u = K\, V_{IN_1} V_{IN_2}}$$

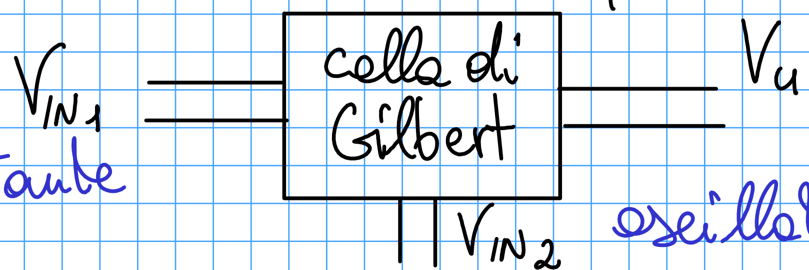
moltiplicatore

limite: ingressi non possono essere forniti con riferimento a massa, ma differenziali



altrimenti i transistor dei terminali "–" entrano in saturazione o interdizione

se ingressi forniti in modo differenziale il sistema lavora correttamente, fino ad ampiezze dell'ordine di V_T



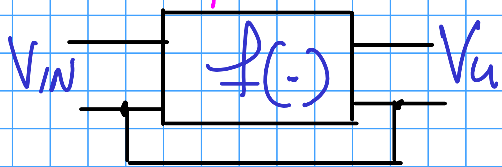
anche come mixer

utilizzi cella di Gilbert

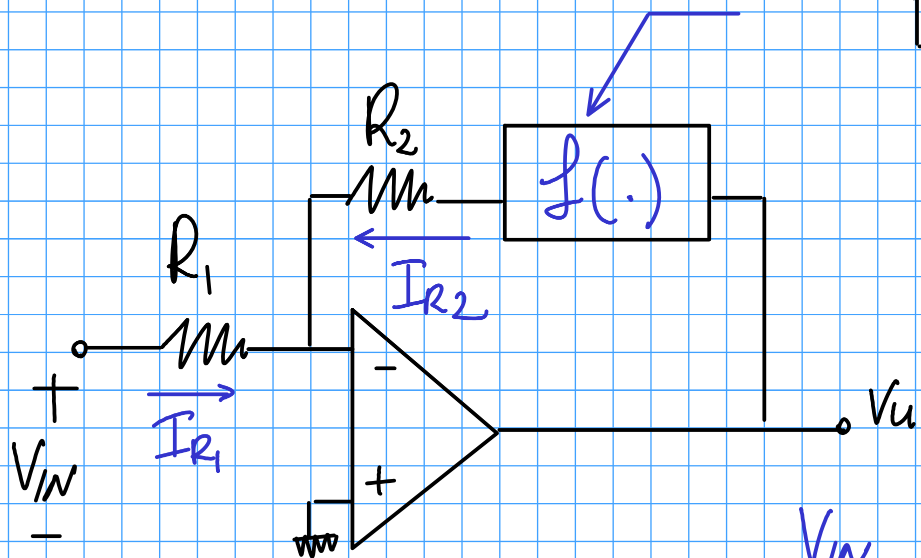
premessa: utilizzo della retroazione per realizzare l'inverso di una qualsiasi funzione $f(\cdot)$ implementata da un blocco inserito nella catena di retroazione

funzione qualsiasi

tripolo



$\longrightarrow V_u = \boxed{f(\cdot)}\, V_{IN}$



$I_{R_1} = -I_{R_2}$ (corto circuito virtuale)

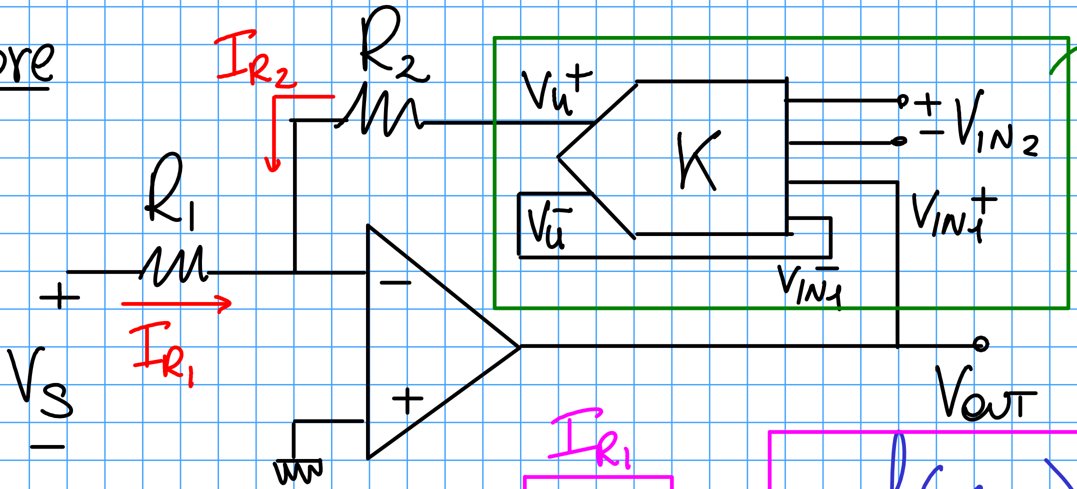
$I_{R_1} = \dfrac{V_{IN}}{R_1}$, $I_{R_2} = \dfrac{f(V_u)}{R_2}$

$$\frac{V_{IN}}{R_1} = -\frac{f(V_u)}{R_2} \longrightarrow V_u = \underline{\underline{f^{-1}}}\left[-\frac{R_2}{R_1} V_{IN}\right]$$

ottengo l'inverso in uscita!

vediamo se posso utilizzare una cella di Gilbert per realizzare un divisore, secondo questa "filosofia" ----

divisore



cella di Gilbert implementa
$V_u = K V_{IN1} V_{IN2}$

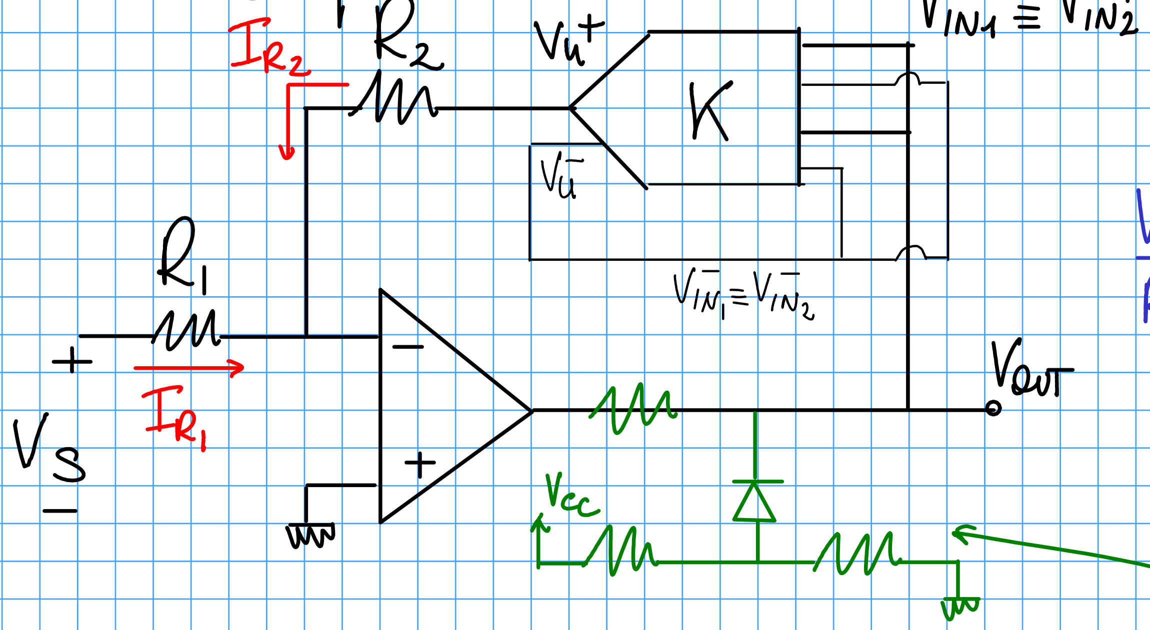
$$I_{R_1} = -I_{R_2} \longrightarrow \underbrace{\boxed{\frac{V_S}{R_1}}}_{I_{R_1}} = \underbrace{\boxed{-\frac{f(V_{OUT})}{R_2}}}_{-I_{R_2}} \longrightarrow \boxed{V_{OUT} = -\frac{1}{K}\frac{R_2}{R_1}\frac{V_S}{V_{IN2}}}$$

$f(V_{OUT}) = K V_{IN_2} V_{OUT}$

limite:

con $V_{IN_2} \sim \phi$ operazionale satura (come fosse open loop)

radice quadrata



$$\frac{V_{IN_2}}{R_1} = -\frac{V_u^2}{K R_2}$$

$$\frac{V_S}{R_1} = -\frac{f(V_{OUT})}{R_2} = -\frac{K V_{OUT}^2}{R_2}$$

$$f(V_{OUT}) = K V_{OUT}^2$$

$$V_{OUT} = \pm\sqrt{-V_S K \frac{R_2}{R_1}}$$

V_S deve essere negativa, altrimenti satura operazionale

$V_{OUT} > 0$, altrimenti ho retroazione positiva | impongo con circuito esterno