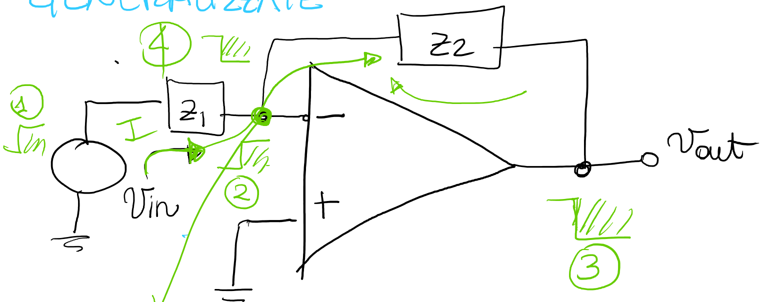
# Lezione 16a: Configurazione invertente con impedenze generalizzate, filtri, diagrammi di Bode....

lunedì 11 maggio 2020 10:29

CONFIGURAZIONE INVERTENTE CON IMPEDENZE GENERALIZZATE

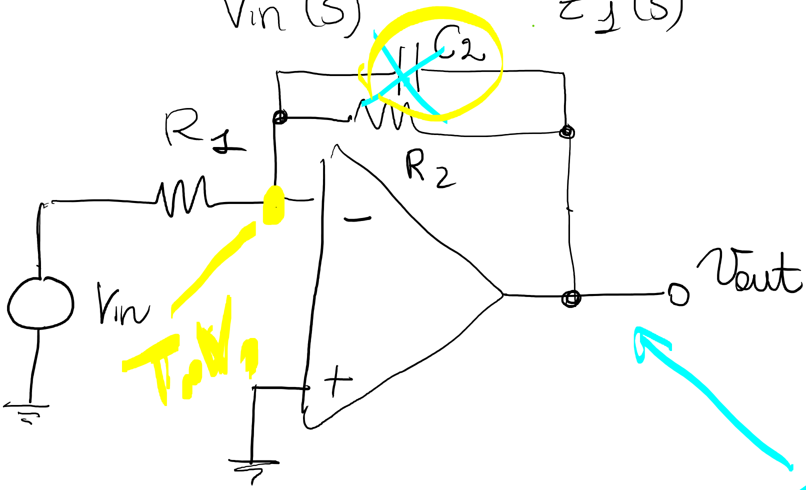



terra virtuale

$$I = \frac{V_{in}(s)}{Z_1(s)}$$

$$V_{out}(s) = -I Z_2(s) = -\frac{V_{in}(s) Z_2(s)}{Z_1(s)}$$

$$T(s) \triangleq \frac{V_{out}(s)}{V_{in}(s)} = -\frac{Z_2(s)}{Z_1(s)}$$




$$Z_1(s) = R_1$$

$$Z_2(s) = \frac{R_2}{1 + sC_2R_2}$$

$$T(s) \triangleq \frac{V_{out}(s)}{V_{in}(s)} = -\frac{Z_2(s)}{Z_1(s)} = -\frac{R_2}{R_1} \frac{1}{1 + sC_2R_2}$$

FUNZIONE DI TRASFERIMENTO

- numero complesso

* GUADAGNO IN CONTINUA $T(0) = -\frac{R_2}{R_1}$

* POLO con $\tau_p = C_2R_2$ $\quad s_p = -\frac{1}{R_2C_2}$

$s = j\omega$

$$T(j\omega) = -\frac{R_2}{R_1} \frac{1}{1 + j\omega RC}$$

* MODULO $|T(j\omega)| = \frac{R_2}{\ } \frac{1}{\ }$ (*)

∗ MODULO $\left|T(j\omega)\right| = \dfrac{R_2}{R_1}\dfrac{1}{\sqrt{1+\omega^2 R_2^2 C_2^2}}$ (∗)

∗ FASE $\arg\left[T(j\omega)\right] = \operatorname{arctg}\left[-\dfrac{R_2}{R_1}\dfrac{1}{1+j\omega R_2 C_2}\right]$

$= -180^\circ + \operatorname{arctg}\left(-\omega R_2 C_2\right)$

(∗) $\left|T(j\omega)\right|_{dB} = 20\log_{10}\left|T(j\omega)\right| =$

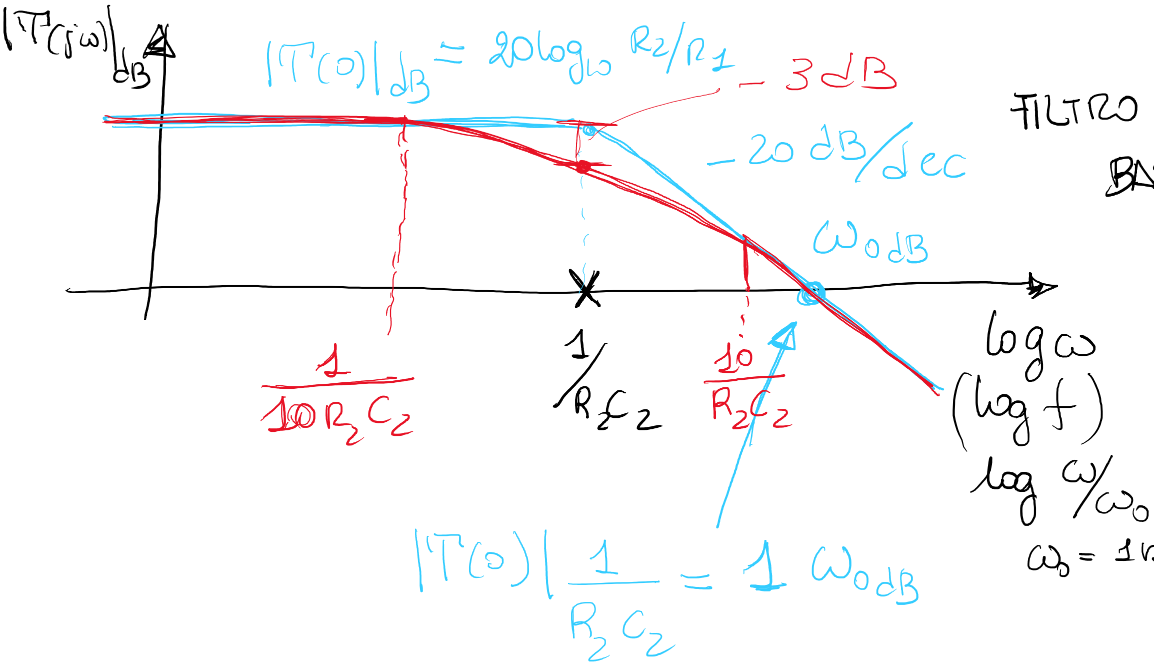
$= 20\log_{10}\dfrac{R_2}{R_1} + 20\log_{10}\dfrac{1}{\sqrt{1+\omega^2 R_2^2 C_2^2}} =$

$= 20\log_{10}\dfrac{R_2}{R_1} - 20\log_{10}\left(\underbrace{\sqrt{1+\omega^2 R_2^2 C_2^2}}\right) =$

$=$

- $\omega \ll 1/R_2C_2$: $20\log_{10}\dfrac{R_2}{R_1}$ $\qquad 1+\omega^2R_2^2C_2^2 \simeq 1$
- $\omega = 1/R_2C_2$: $20\log_{10}\dfrac{R_2}{R_1} - 20\log_{10}\sqrt{2} =$ $\qquad \sqrt{2}$
  $= 20\log_{10} R_2/R_1 - 3\,dB$
- $\omega \gg \dfrac{1}{R_2C_2}$: $\underbrace{20\log_{10}\dfrac{R_2}{R_1} - 20\log_{10}\omega R_2C_2}$ $\qquad \sqrt{\omega^2R_2^2C_2^2} = \omega R_2 C_2$

DIAGRAMMA DI BODE DEL MODULO



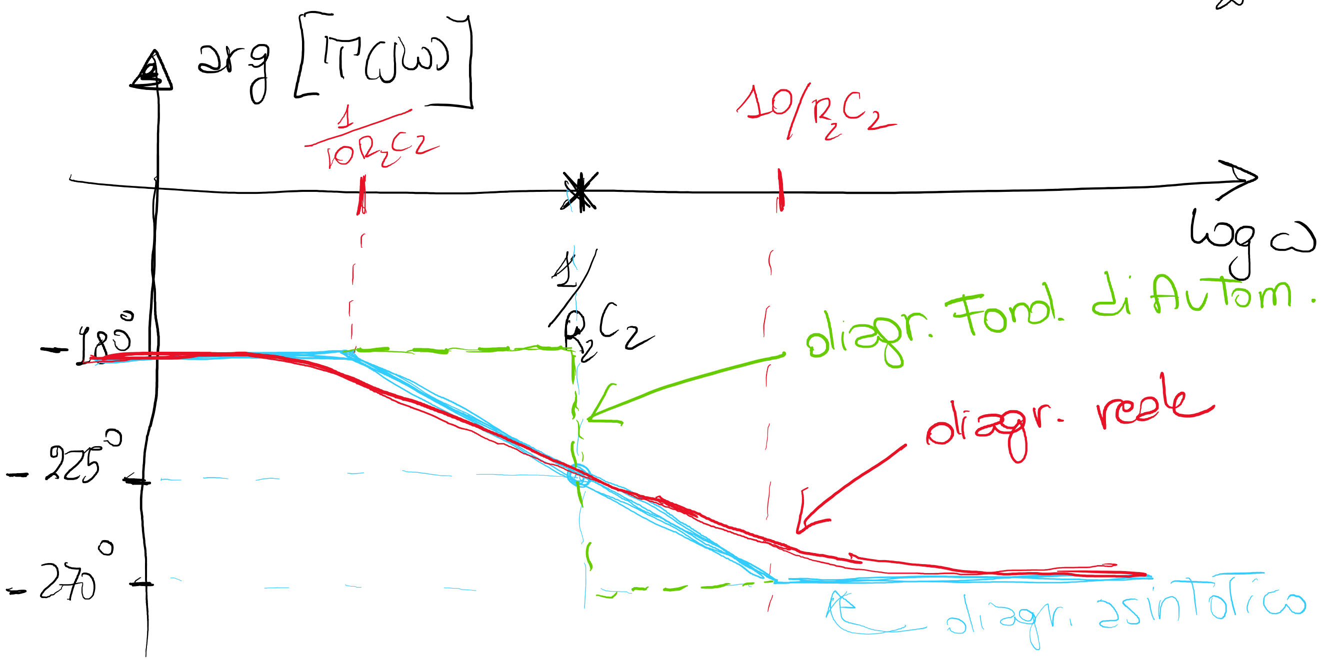

FILTRO PASSA BASSO

$\omega_0 = 1\,rad/s$

# DIAGRAMMA DI BODE DELLA FASE

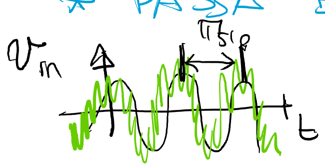
$$\arg\left[T(j\omega)\right] = -180° - \arctan \omega R_2 C_2 =$$

$$= \begin{cases} -180° = -\pi & \omega \ll 1/R_2C_2 \\ -180° - \arctan 1 = -225° = -\frac{5}{4}\pi & \omega = 1/R_2C_2 \\ -180° - 90° = -270° = -\frac{3}{2}\pi & \omega \gg 1/R_2C_2 \end{cases}$$

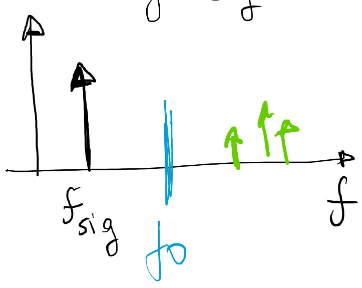


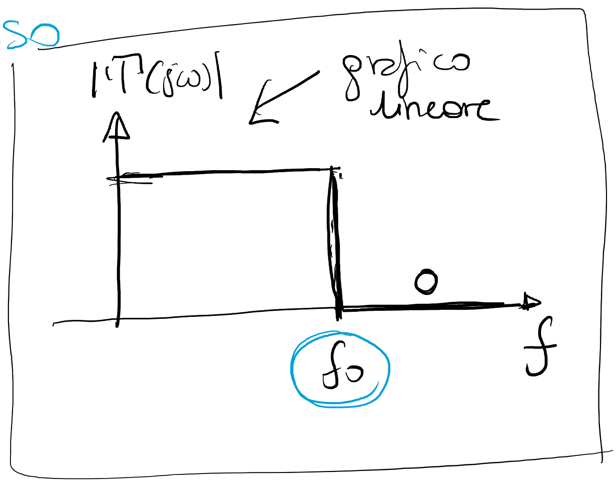

## FILTRI ATTIVI DEL PRIMO ORDINE

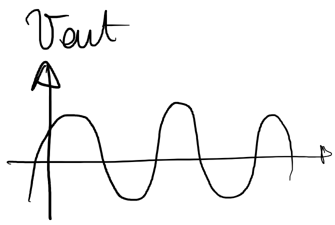
* PASSA BASSO

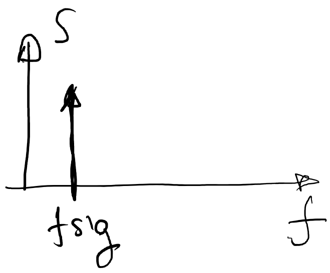



Sin $f_{sig} = \frac{1}{T_{sig}}$



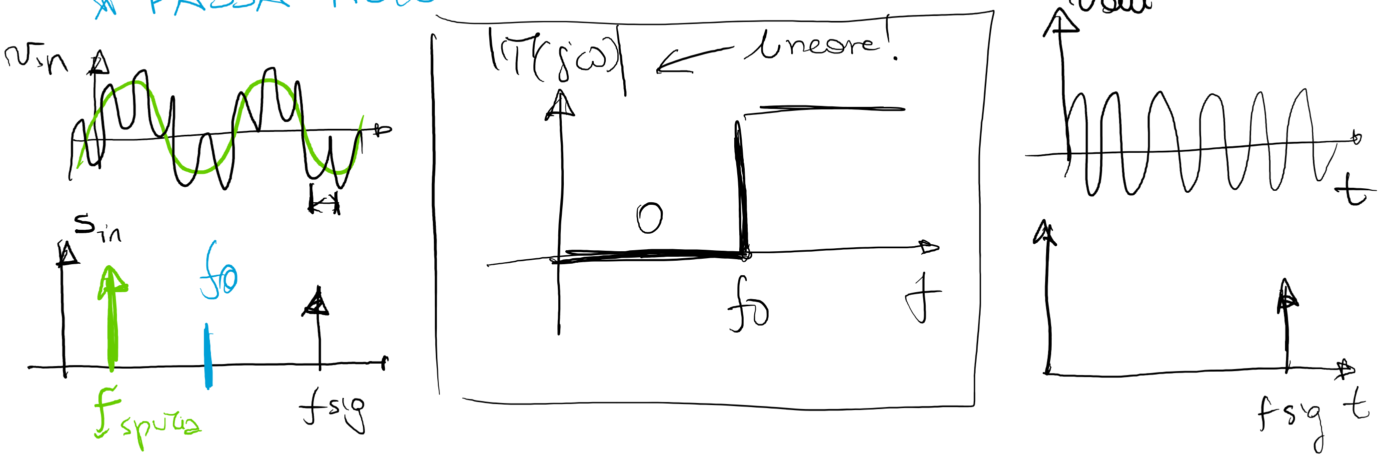




* PASSA ALTO

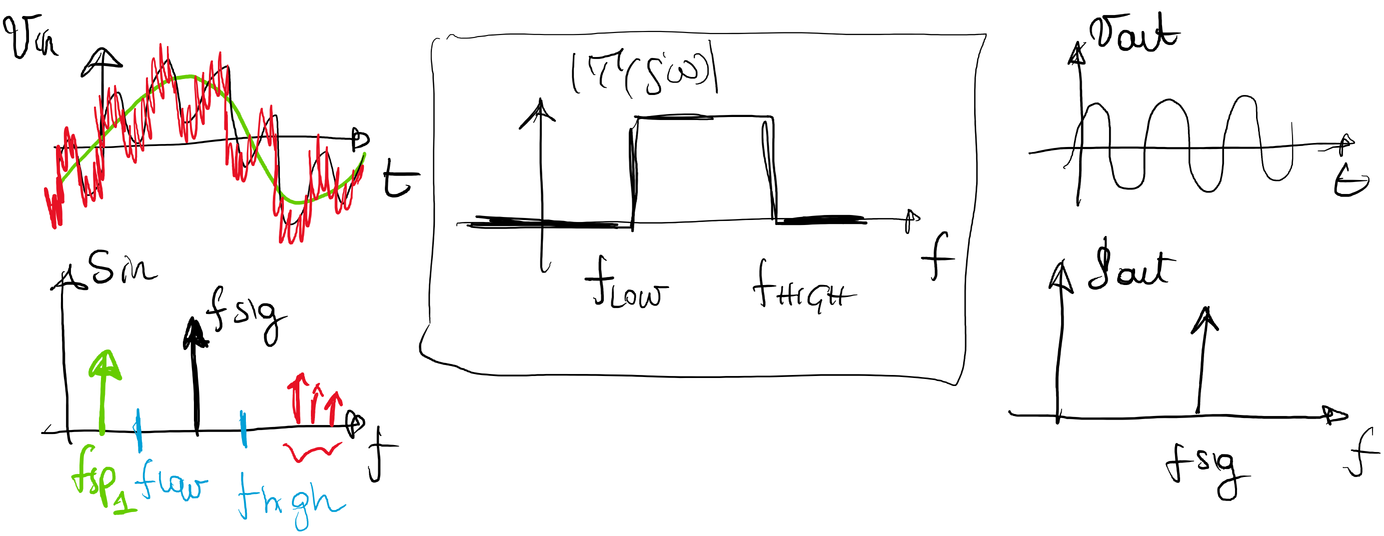
|T(jω)| ← lineare

Vout

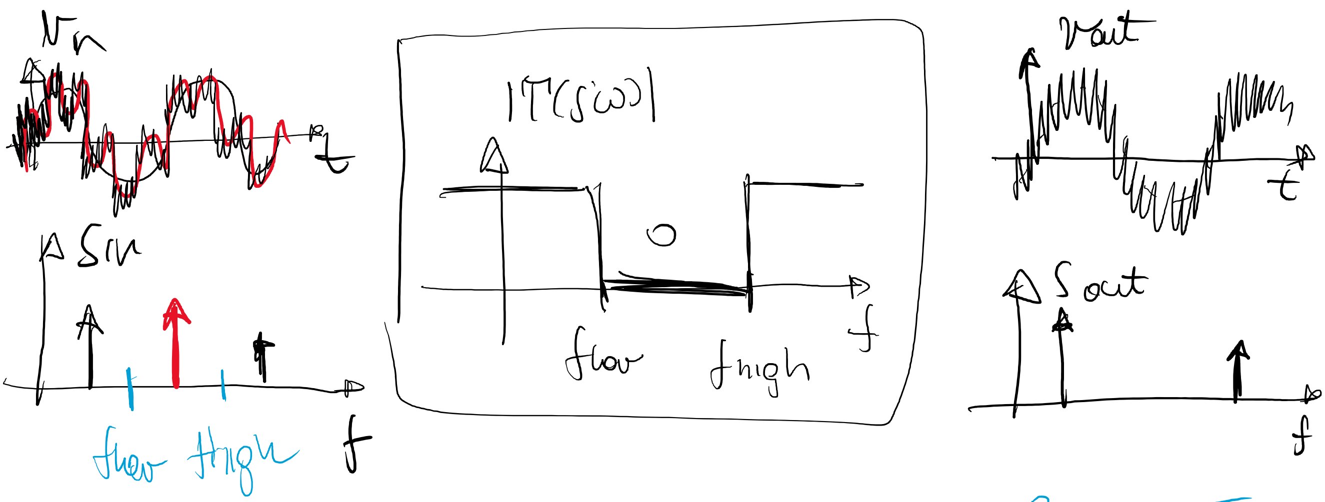
* PASSA ALTO




* FILTRO PASSA-BANDA

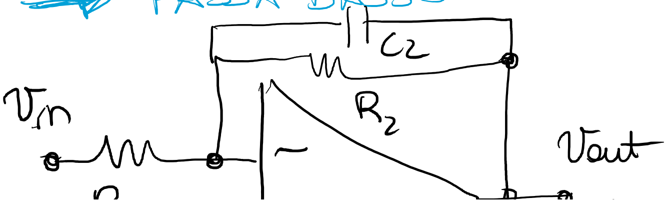



* FILTRO ARRESTA-BANDA




IMPLEMENTAZIONI CIRCUITALI FILTRI DEL 1° ORDINE

→ PASSA BASSO

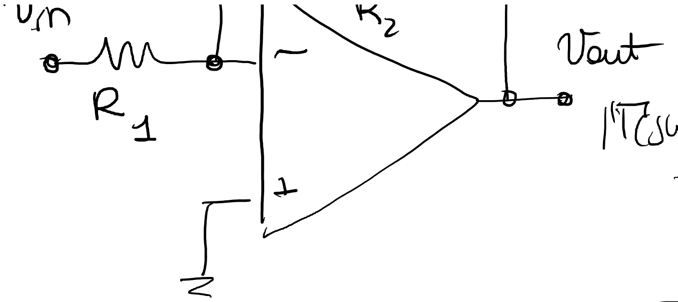


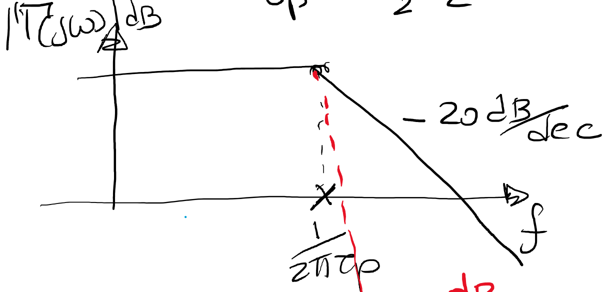

$$T(s) \triangleq \frac{V_{out}(s)}{V_{in}(s)} = -\frac{R_2}{R_1} \cdot \frac{1}{1+s\tau_p}$$

$$\tau_p = R_2 C_2$$

$V_{in}(s)$

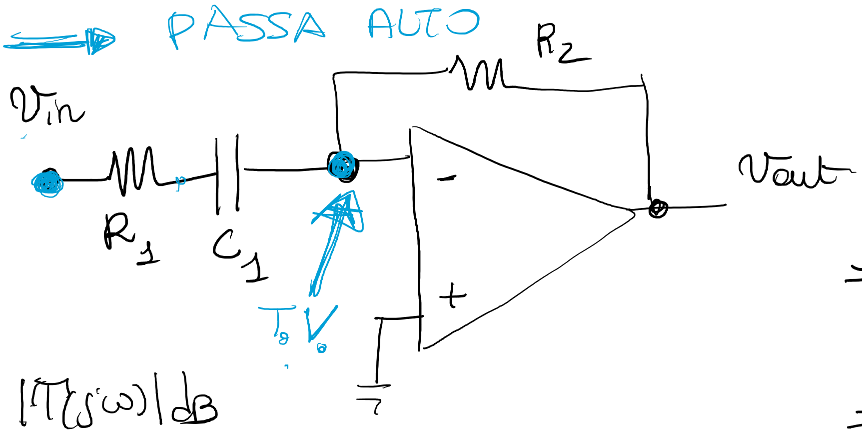
$\tau_p = R_2 C_2$



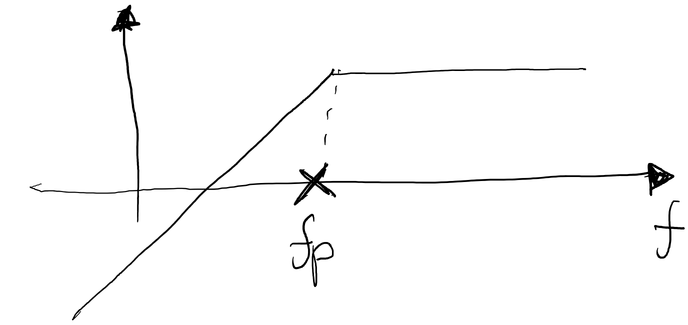




$-80\ dB/dec$ se fosse filtro del 4° ordine!!

## ⟹ PASSA ALTO



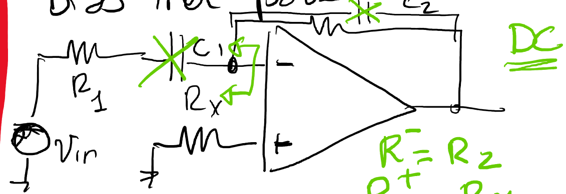

$$T(s) \triangleq \frac{V_{out}(s)}{V_{in}(s)} = -\frac{R_2}{R_1 + 1/sC_1} = -\frac{sC_1R_2}{1+sC_1R_1}$$




- $\tau_p = C_1 R_1$
- zero nell'origine

$f_p = 1/2\pi\tau_p$

Compensazione correnti di bias nel passa-banda

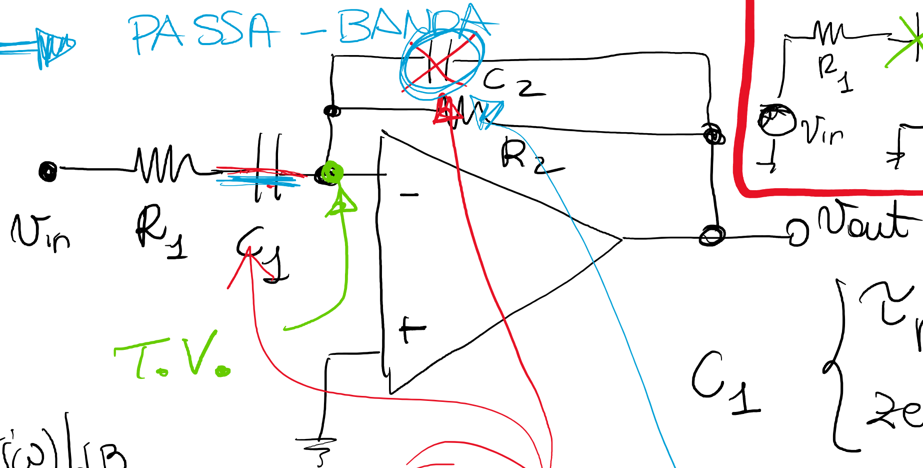



$R^- = R_2$

$R^+ = R_x$

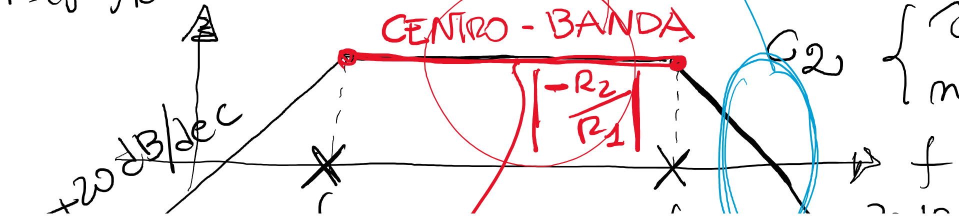
$\hookrightarrow R_x = R_2$

## ⟹ PASSA-BANDA

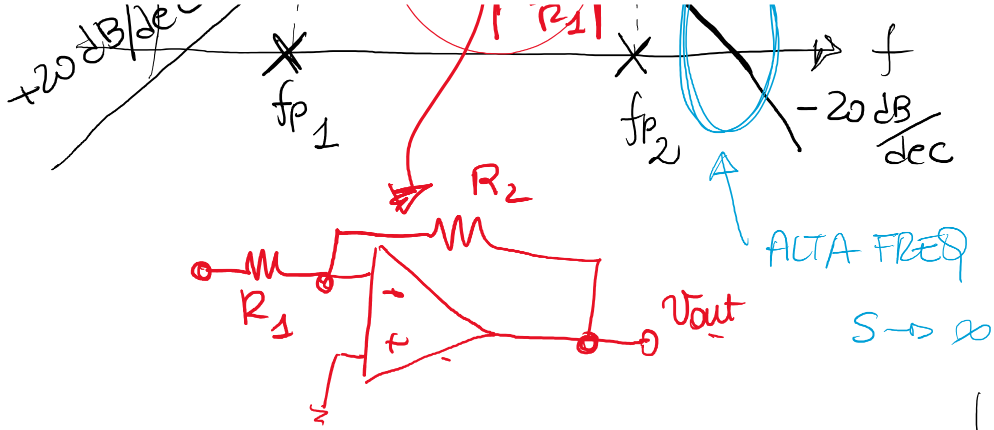



$C_1$ $\begin{cases} \tau_{p_1} = C_1R_1 \\ \text{zero nell'origine} \end{cases}$

$C_2$ $\begin{cases} \tau_{p_2} = C_2R_2 \\ \text{niente zeri al finito} \end{cases}$




$f_{p_1} = \frac{1}{2\pi\tau ...}$




$$f_{p_1} = \frac{1}{2\pi \tau_{p_1}}$$

$$f_{p_2} = \frac{1}{2\pi \tau_{p_2}}$$

$s \to \infty \quad |T(j\omega)| \to 0$

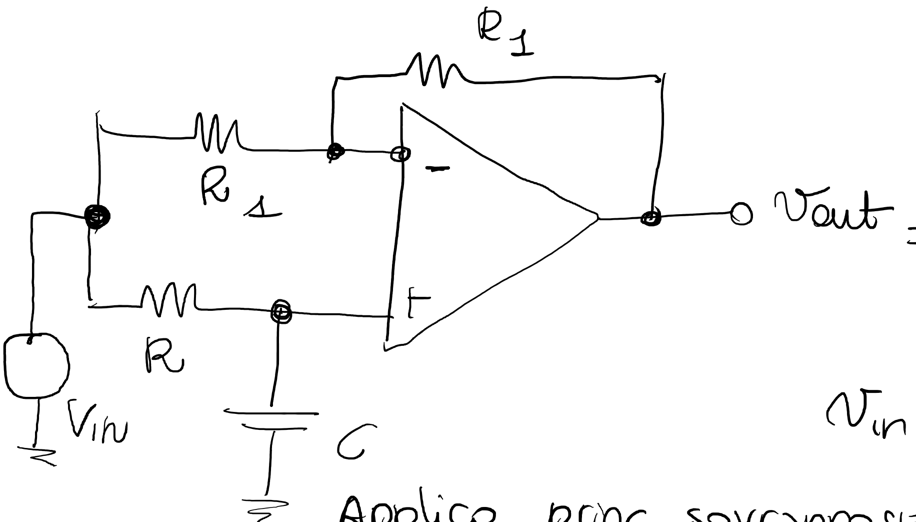
$$T(s) = -\frac{Z_2(s)}{Z_1(s)} = -\frac{R_2}{1+sC_2R_2} \cdot \frac{1}{R_1 + \frac{1}{sC_1}} =$$

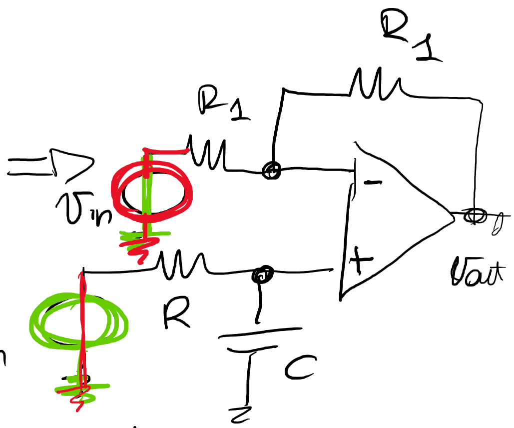
$$Z_2(s) = \frac{R_2}{1+sC_2R_2}$$

$$Z_1 = R_1 + \frac{1}{sC_1}$$

$$= -\frac{sC_1R_2}{(1+sC_2R_2)(1+sC_1R_1)}$$

$\Rightarrow$ PASSA-TUTTO (SFASATORE PURO) [PHASE SHIFTER]




Applico princ. sovrapposiz. effetti

$$V_{out} = \frac{1/sC}{R + 1/sC} \cdot \underbrace{\left(1 + \frac{R_1}{R_1}\right)}_{2} V_{in} - \underbrace{\frac{R_1}{R_1}}_{1} V_{in}$$

$$T(s) = \frac{1/sC}{R + 1/sC}\, 2 - 1 =$$

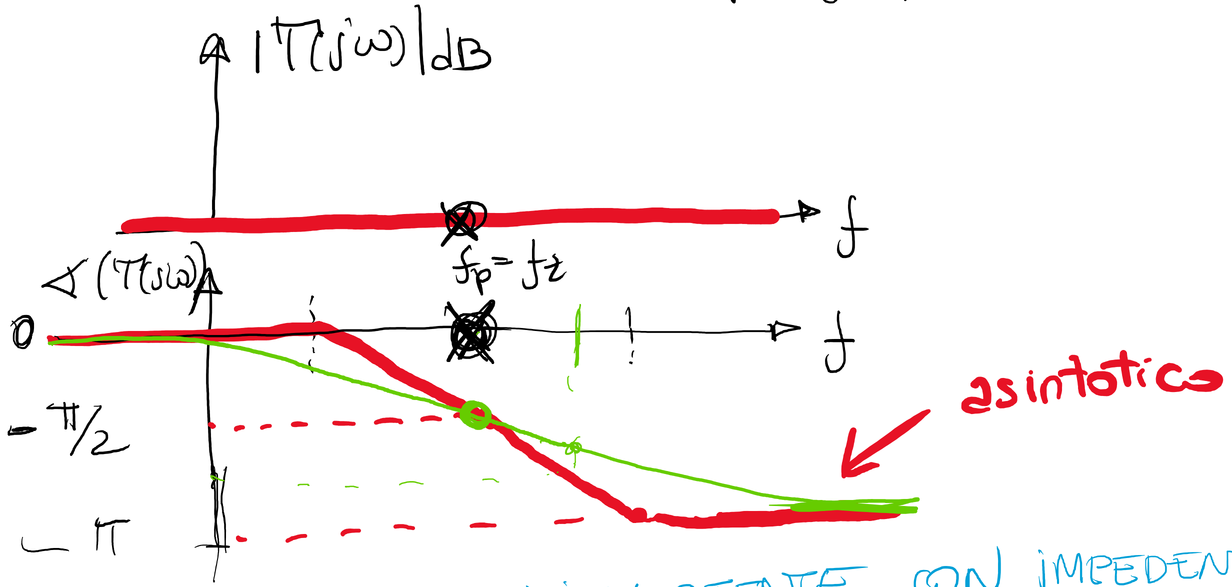
$$= 2\,\frac{1}{1+sCR} - 1 =$$

$$2 - 1 - sCR \qquad 1 - sCR$$

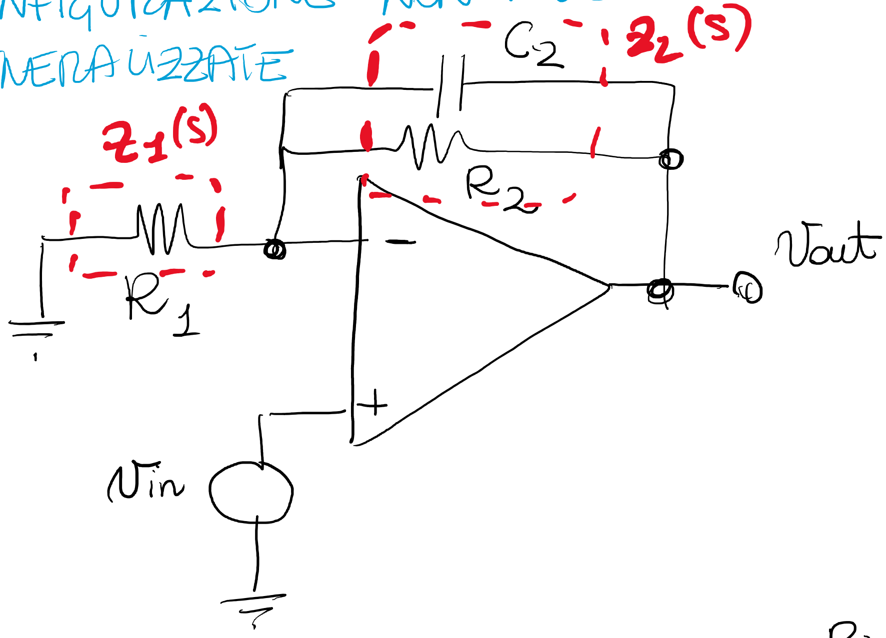
$$= \frac{2 - 1 - sCR}{1 + sCR} = \frac{1 - sCR}{1 + sCR}$$

* polo $\quad s_p = -\,1/RC \quad \tau_p = RC \quad (sx)$
* zero $\quad s_z = +\,1/RC \quad \tau_z = RC \quad (dx)$

$$|T(j\omega)| = \left| \frac{1 - j\omega RC}{1 + j\omega RC} \right| = \frac{\sqrt{1+\omega^2R^2C^2}}{\sqrt{1+\omega^2R^2C^2}} = 1$$




CONFIGURAZIONE NON INVERTENTE CON IMPEDENZE GENERALIZZATE




$$Z_2(s) = \frac{R_2}{1 + sC_2R_2}$$

$$Z_1 = R_1$$

$$T(s) = 1 + \frac{Z_2(s)}{Z_1(s)} = 1 + \frac{\frac{R_2}{1+sC_2R_2}}{R_1} =$$

$$= 1 + \frac{R_2}{R_1(1+sC_2R_2)} = \frac{R_1 + sC_2R_2R_1 + R_2}{R_1(1+sC_2R_2)} =$$

$$= \frac{(R_1+R_2)}{R_1} \cdot \frac{1 + sC_2 \frac{R_2R_1}{R_1+R_2}}{1+sC_2R_2} =$$

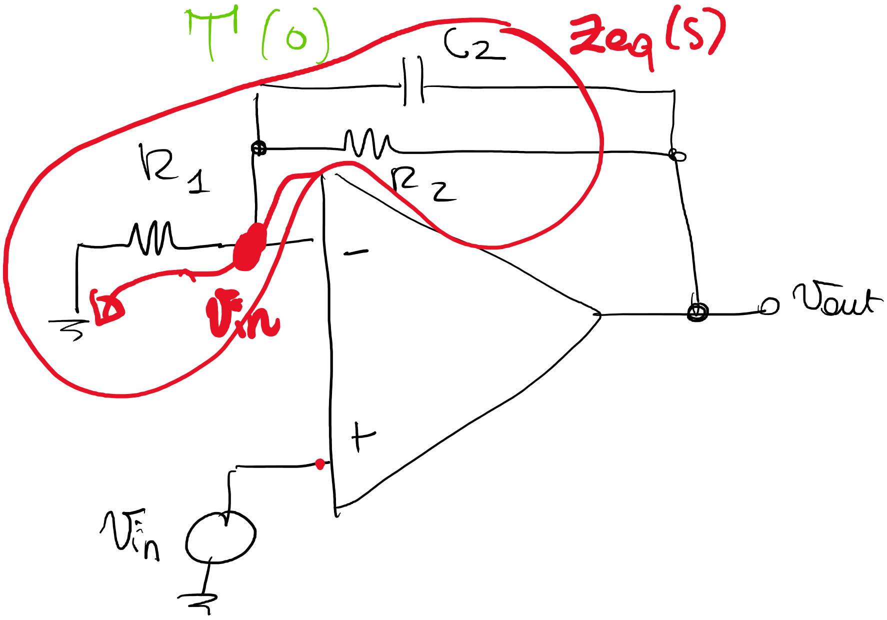
$R_1 /\!/ R_2$

$$= \left(1 + \frac{R_2}{R_1}\right) \frac{1 + sC_2(R_1 /\!/ R_2)}{1 + sC_2R_2}$$

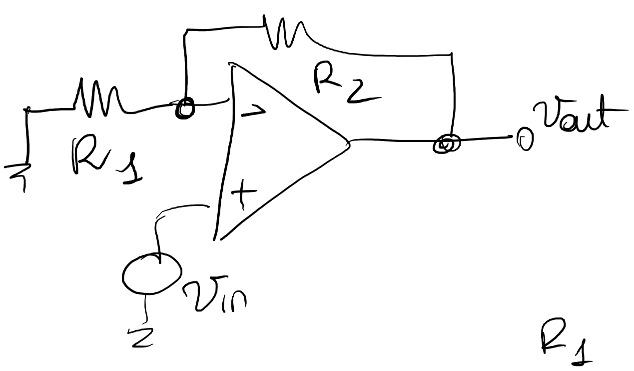
ZERO $\tau_z = C_2(R_1 /\!/ R_2)$

GUADAGNO IN CONTINUA $T(0)$

POLO $\tau_p = C_2R_2$

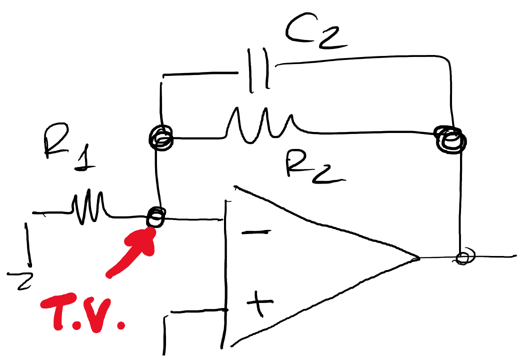



• guadagno in continua ($f=0 \Rightarrow$ capacità circ. aperti)

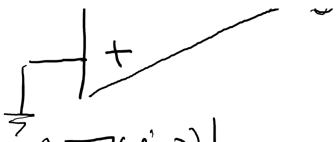


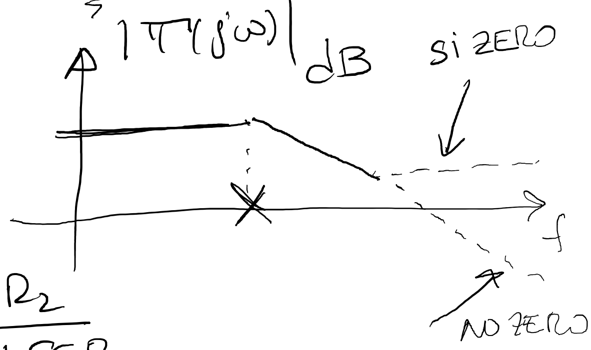

$$T(0) = 1 + \frac{R_2}{R_1}$$

• polo $\tau_p = C_2R_2$



T.V.






• zero?

$$\exists\ \bar{s}\ \text{t.c.}\ \forall\ v_{in}(\bar{s}) \neq 0$$
$$v_{out}(\bar{s}) = 0$$

$z_{eq}(s) = 0$ dove $z_{eq}(s) = R_1 + \dfrac{R_2}{1+sC_2R_2}$

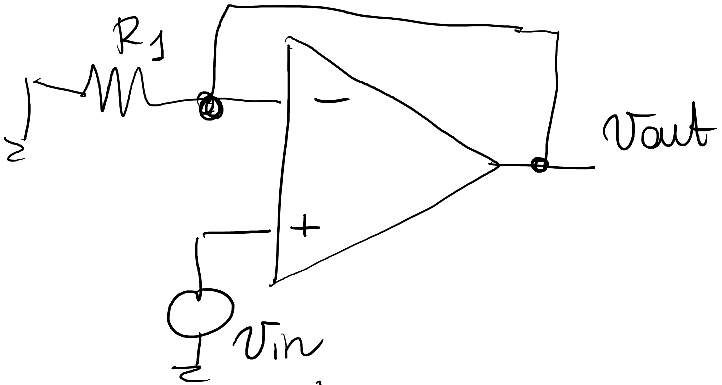
$$z_{eq}(s) = R_1 + \frac{R_2}{1+sC_2R_2} = R_1 + sC_2R_2R_1 + R_2 = (R_1+R_2)\left[1+sC_2\frac{R_1R_2}{R_1+R_2}\right]$$

$$= (R_1+R_2)\left[1+sC_2(R_1 /\!/ R_2)\right]$$

$$\Downarrow\ s_z = -\frac{1}{C_2(R_1 \| R_2)}$$

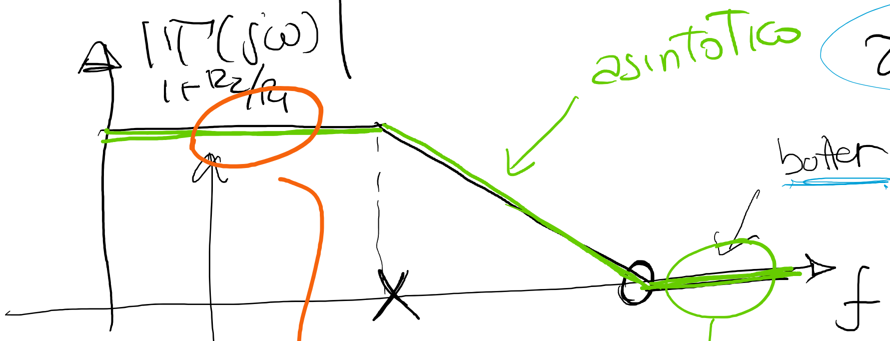
$\hookrightarrow \tau_z = C_2(R_1 \| R_2)$

in alta freq. $C_2$ è assimibbile a un corto circuito

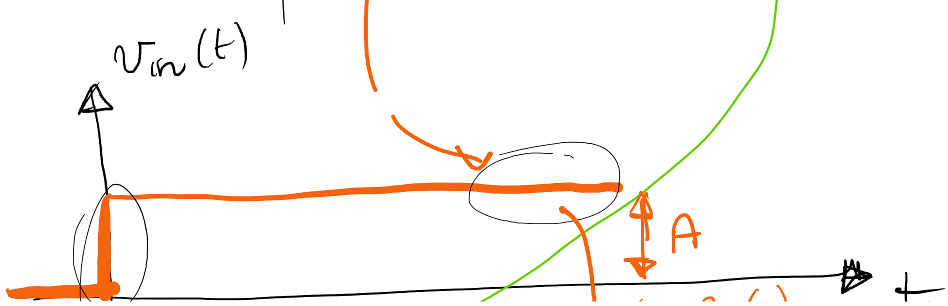


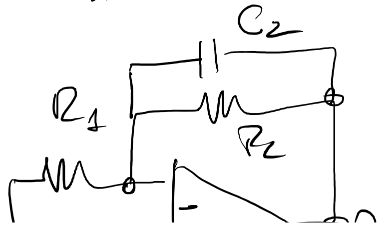

È UN BUFFER

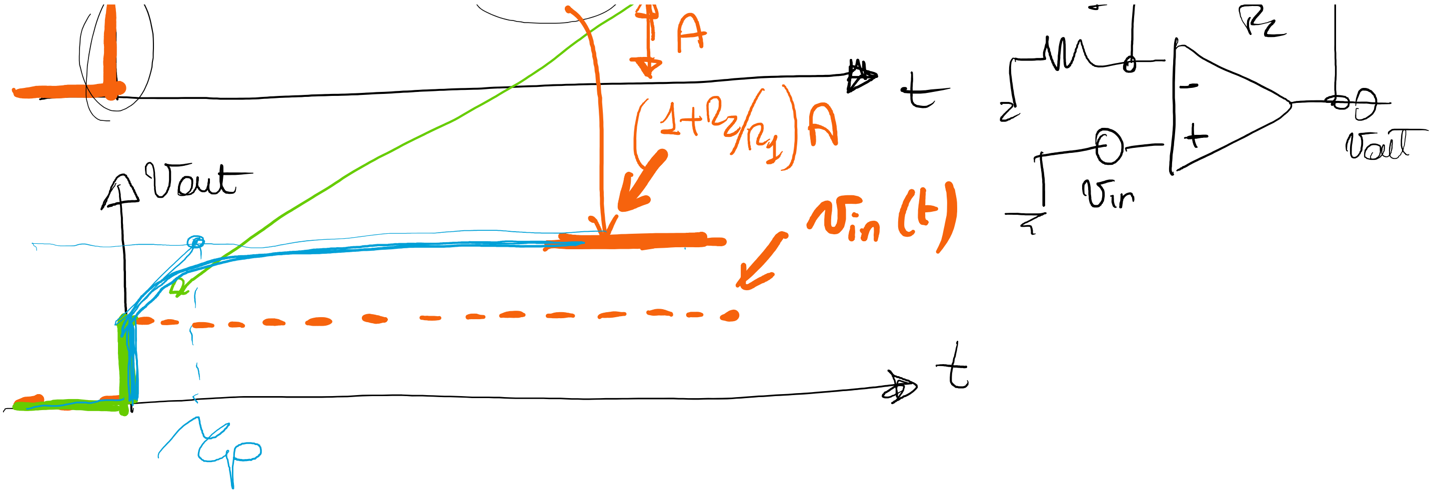
$$|T(j\omega)|_{HF} = 1$$




$$\tau_p = C_2R_2$$
$$\tau_z = C_2\ R_1 \| R_2$$
$$\tau_z < \tau_p$$
$$\Downarrow$$
$$f_z > f_p$$





A
t
$(1+R_2/R_1)A$
$V_{out}$
$v_{in}(t)$
t
$\tau_p$
$R_2$
$V_{out}$
$v_{in}$