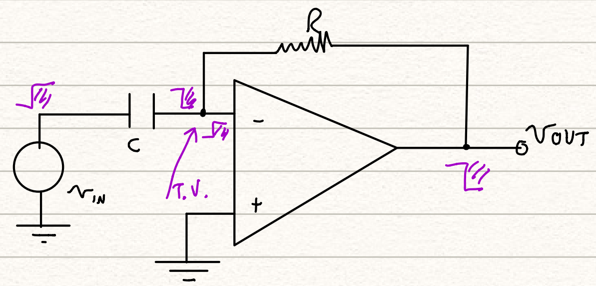
STABILITÀ E COMPENSAZIONE, STADIO DERIVATORE E RETROAZIONE POSITIVA

CIRCUITO DERIVATORE: STABILITÀ E COMPENSAZIONE

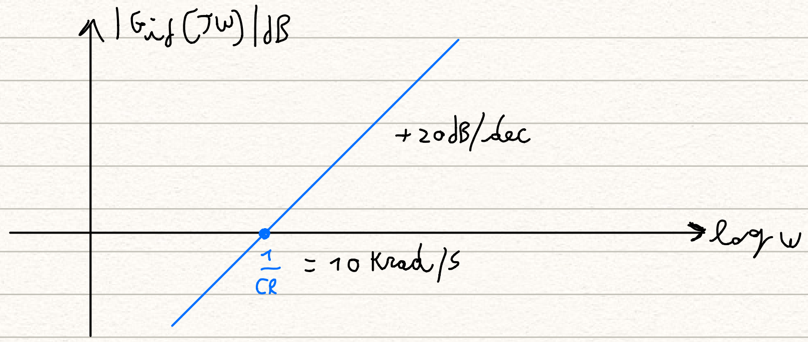


$Z_2(s) = R$

$Z_1(s) = \frac{1}{sC}$

$G_{id}(s) = -\frac{Z_2(s)}{Z_1(s)} = -RsC = -s\,CR$ ← derivatore

$CR = 10^{-8} \cdot 10^{4} = 10^{-4}\,s = 100\,\mu s$



ASSUMIAMO $A(s) = \frac{A_0}{1 + s\tau_0}$

$A_0 = 80\,dB$

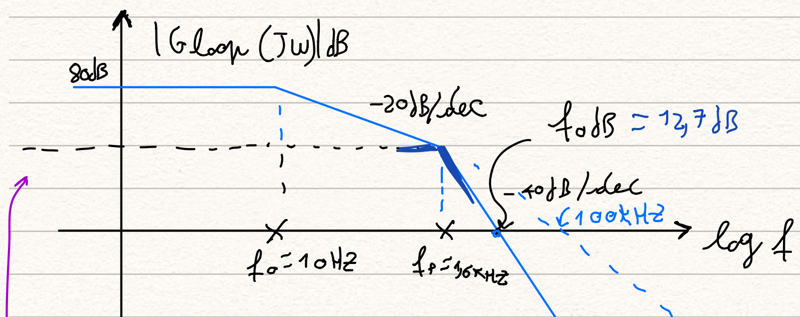
$\tau_0 = 15,9\,ms$

$\hookrightarrow f_0 = \frac{1}{2\pi\tau_0} = 10\,Hz$

STABILITÀ?

calcolo Gloop $\longrightarrow$ $G_{loop}(s) = \frac{1/sC}{R + 1/sC}$ $A(s) = \frac{-A_0}{1 + RsC} \cdot \frac{1}{1 + s\tau_0}$

2 POLI



$$|G_{loop}(0)| \cdot f_0 = |G_{loop}(f_p)| \cdot f_p$$

$$|G_{loop}(f_p)| = \frac{|G_{loop}(0)|\, f_0}{f_p} = +36\,dB$$

$$36\,dB - 0\,dB = 40 \log \frac{f_{0dB}}{f_p}$$

$$f_{0dB} = 12{,}7\,KHz$$

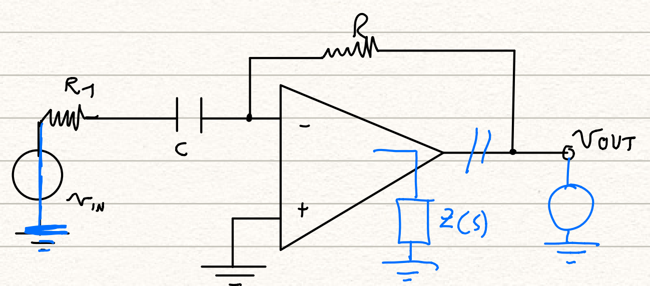
MARGINE DI FASE:

$$\phi_m = \left[-180^\circ - \text{arctg}\frac{f_{0dB}}{f_0} - \text{arctg}\frac{f_{0dB}}{f_p}\right] - (-360^\circ) = -180^\circ - 90^\circ - 83^\circ + 360^\circ = +7^\circ$$

MATEMATICAMENTE SAREBBE STABILE ($\phi_m > 0$)

MA IN PRATICA $\phi_m < 45^\circ \longrightarrow$ NON VA BENE!

DERIVATORE APPROSSIMATO



$$Z_2(s) = R$$

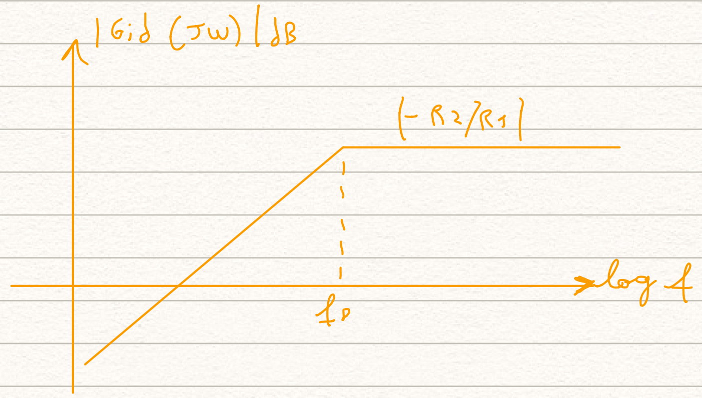
$$Z_1(s) = \frac{1}{sC} + R_1 = \frac{1 + sCR_1}{sC}$$

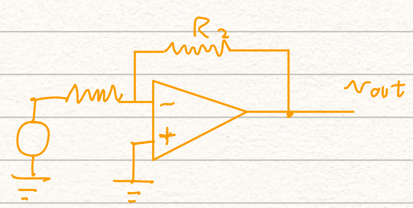
ZERO NELL' ORIGINE

$$G_{id}(s) = \frac{-Z_2(s)}{Z_1(s)} = -\frac{sRC}{\underbrace{1 + sCR_1}}$$

POLO CON $\tau_p = CR_1$

$$f_p = \frac{1}{2\pi\tau_p}$$





GUADAGNO D'ANELLO

$$G_{loop}(s) = -\frac{R_1 + 1/sC}{R + R_1 + 1/sC} \cdot A(s) = -\frac{1 + sCR_1}{\underbrace{1 + sC(R+R_1)}} \cdot \frac{A_0}{1 + s\tau_0}$$

$\tau_p = C(R+R_1)$

$\tau_z = CR_1$

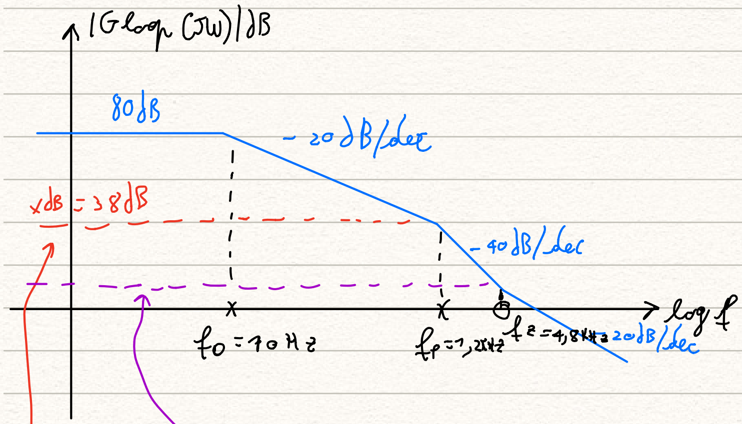
scegliendo:

$R_1 = 1/3\,R = 3{,}3\,k\Omega$

2 POLI $\qquad f_0 = 10\,Hz$

$f_p = \frac{1}{2\pi\tau_p}$

1 ZERO $\qquad f_p = \frac{1}{2\pi\tau_z}$



$10^4 \cdot f_0 = x \cdot f_p \longrightarrow x = \frac{10^4 f_0}{f_p} \longrightarrow 38\,dB$

$38\,dB - y = 40 \log \frac{f_z}{f_p} \longrightarrow y = 14\,dB$

$14\,dB - 0\,dB = 20 \log \frac{f_{0dB}}{f_z}$

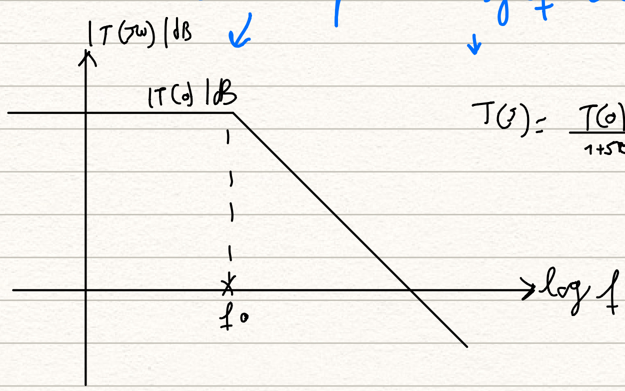
$\downarrow$

$f_{0dB} = 24\,kHz$

MARGINE DI FASE

$$\phi_m = \Big[-180° - \overset{-90°}{\operatorname{arctg}\frac{f_{0dB}}{f_0}} - \overset{-90°}{\operatorname{arctg}\frac{f_{0dB}}{f_p}} + \underset{+79°}{\operatorname{atg}\frac{f_{0dB}}{f_z}}\Big] - (-360°) = +79°\ !!!$$

come questi i grafici?



$T(s) = \frac{T(0)}{1 + s\tau_0}$

$T(s) \approx \frac{T(0)}{s\tau_0}$

$f_0 = \frac{1}{2\pi\tau_0}$

$|T(j\omega)| = \frac{|T(0)|}{\sqrt{1 + \omega^2\tau_0^2}}$

$f \gg f_0 \qquad |T(j\omega)| \simeq \dfrac{|T(0)|}{\omega \tau_0}$

$\omega = \bar{\omega} \qquad |T(j\bar{\omega})|_{\bar{\omega}} = |T(0)| \dfrac{1}{\tau_0}$

$\forall \omega \; (\omega > \omega_0) \quad |T(j\omega)|\omega = |T(0)| \, 1/\tau_0$

$20 \log_{\omega} |T(j\omega)| + 20 \log_{10} \omega = 20 \log |T(0)| + 20 \log |1/\tau_0|$

$|T(j\omega)|_{dB} - |T(0)|_{dB} = 20 \log \dfrac{|1/\tau_0|}{\omega}$

2 poli

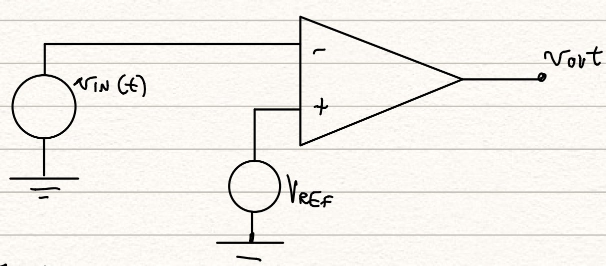
$T(s) = \dfrac{T(0)}{(1+s\tau_1)(1+s\tau_2)}$

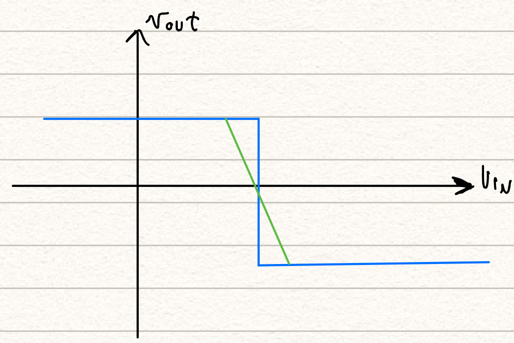
$f_1 = \dfrac{1}{2\pi \tau_1} \qquad f_2 = \dfrac{1}{2\pi \tau_2}$

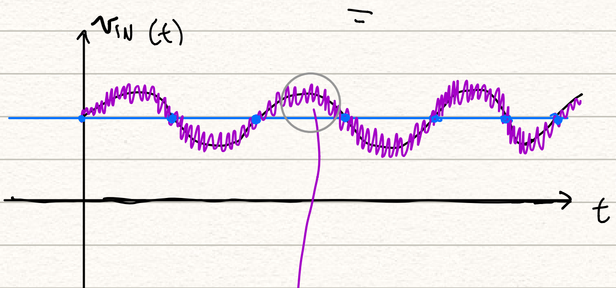
$f_1 \ll f \ll f_2 \qquad T(s) \simeq \dfrac{T(0)}{s\tau_1}$

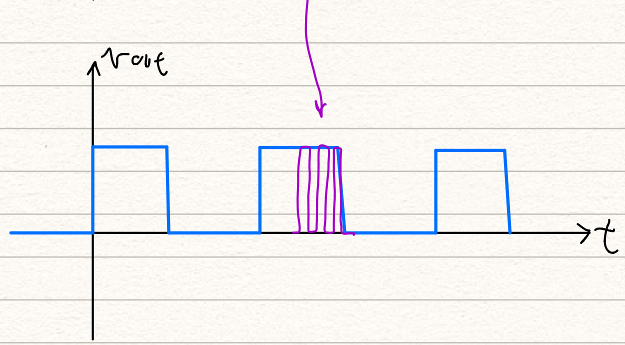
$f \gg f_2 \qquad T(s) \simeq \dfrac{T(0)}{s^2 \tau_1 \tau_2}$

RETROAZIONE POSITIVA:



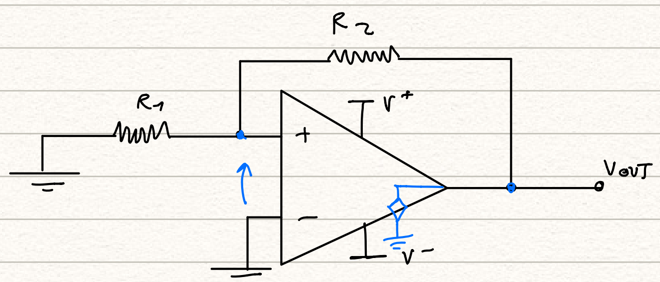






per evitare le commutazioni spurie per effetto del rumore → comparatore con isteresi

TRIGGER DI SCHMITT



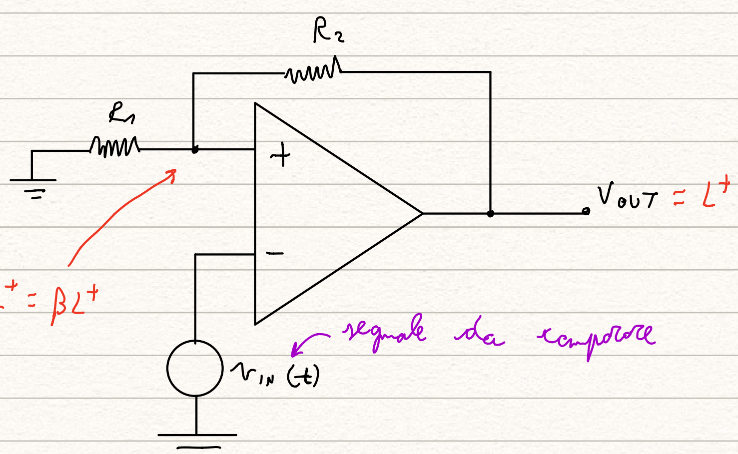
L^+ livello di saturazione positiva di V_{OUT}
L^- livello di saturazione negativa di V_{OUT}
$L^- \leq V_{OUT} \leq L^+$

SOLO DUE STATI STABILI:

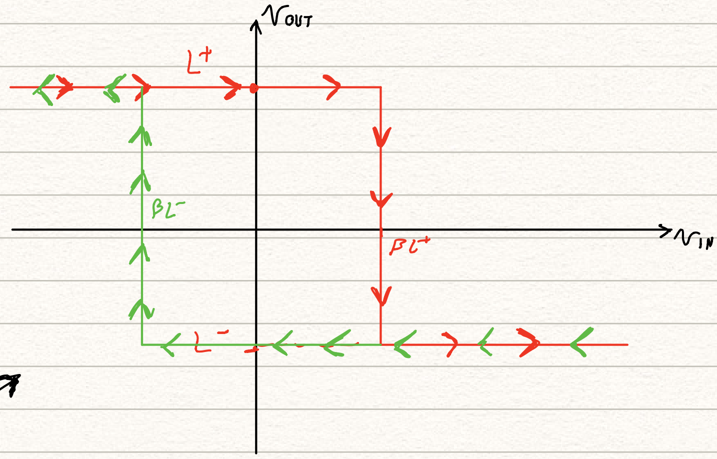
- $V_{OUT} = L^+ \longrightarrow v^+ = \dfrac{R_1}{R_1+R_2} L^+$
- $V_{OUT} = L^- \longrightarrow v^+ = \underbrace{\dfrac{R_1}{R_1+R_2}}_{\beta} L^- = \beta L^-$

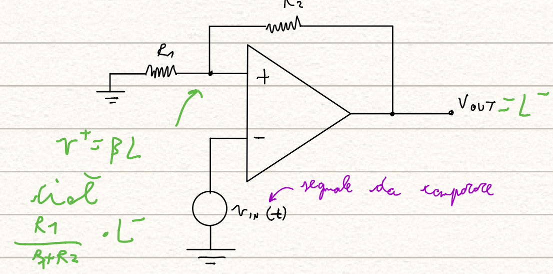
CIRCUITO BISTABILE

TRIGGER DI SCHMITT IN CONFIGURAZIONE INVERTENTE:

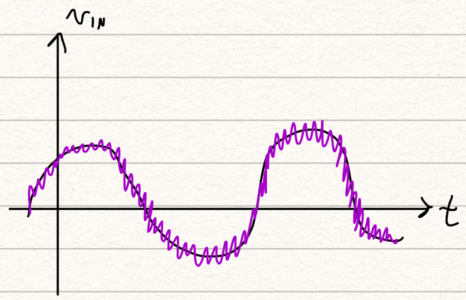


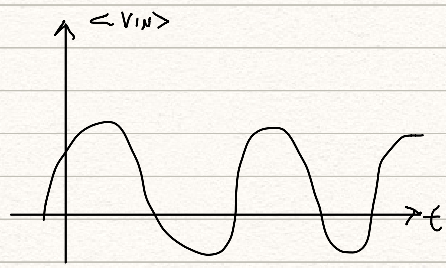
$v^+ = \dfrac{R_1}{R_1+R_2} L^+ = \beta L^+$

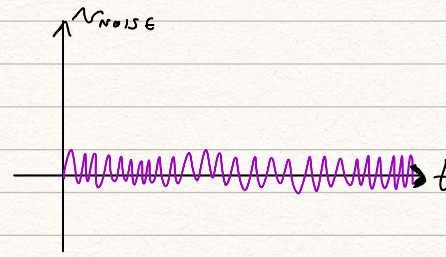


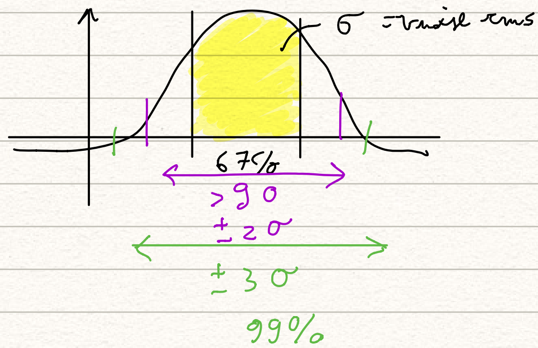


CARATTERISTICA DI TRASFERIMENTO STATICA TRIGGER DI SCHMITT INVERTENTE

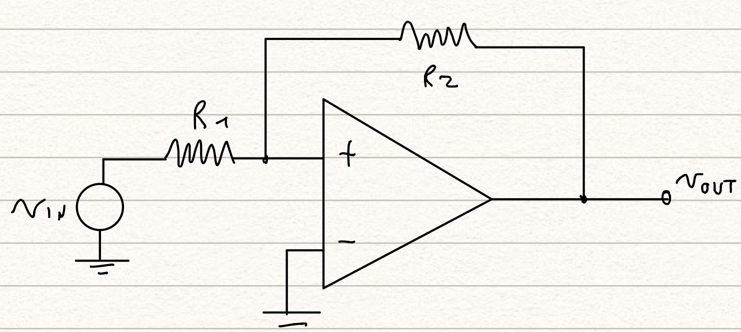






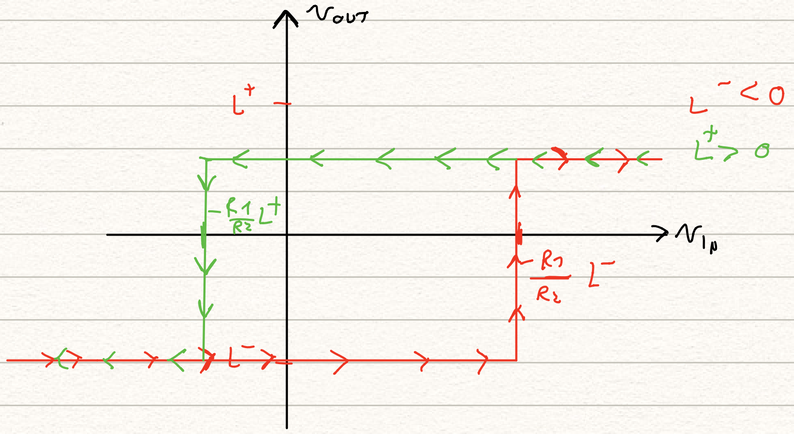


CONFIGURAZIONE NON INVERTENTE:



$L^- < 0$

$L^+ > 0$



$$v^+ = \frac{R_1}{R_1+R_2} V_{out} + \frac{R_2}{R_1+R_2} v_{IN}$$

$$V_{OUT} = L^-$$

$$v^+ = \frac{R_1}{R_1+R_2} L^- + \frac{R_2}{R_1+R_2} V_{IN}$$

per quale v_{IN} $v^+ = 0$

$$0 = \frac{R_1}{R_1+R_2} L^- + \frac{R_2}{R_1+R_2} v_{IN}$$

$$v_{IN} = -\frac{R_1 L^-}{R_2} = -\frac{R_1}{R_2} L^- > 0$$

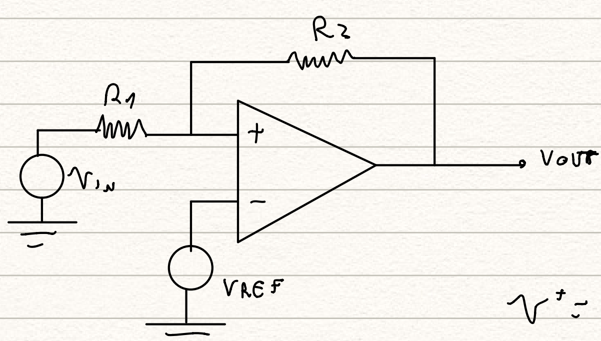
$$v_{OUT} = L^+$$

per quale v_{IN} $v^+ = 0$?

$$0 = \frac{R_1}{R_1+R_2} L^+ + \frac{R_2}{R_1+R_2} V_{IN}$$

$$V_{IN} = -\frac{R_1}{R_2} L^+ < 0$$

Come effettuare la comparazione non rispetto a 0V?



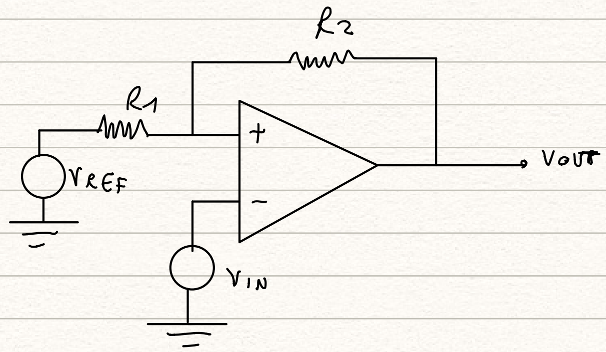
?

$$v^+ = \frac{R_2}{R_1+R_2} V_{IN} + V_{OUT} \frac{R_1}{R_1+R_2}$$

La commutazione si ha per $V_\varepsilon = 0$

$v^+ = v^- = V_{REF}$

$$\frac{R_2}{R_1+R_2} V_{IN} + \frac{R_1}{R_1+R_2} V_{OUT} = V_{REF}$$



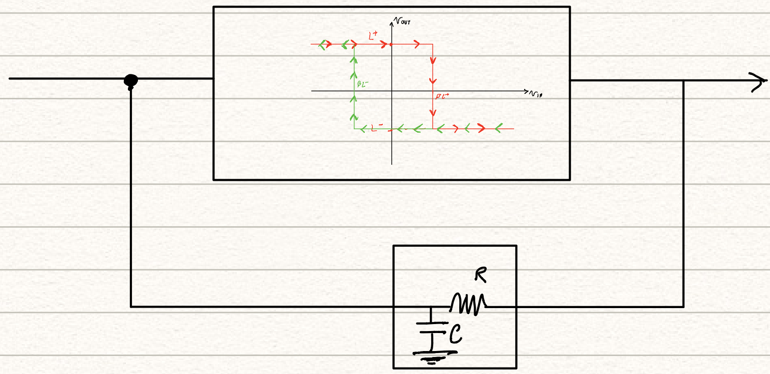
condizione di commutazione $v_\varepsilon = 0$, cioè $v^+ = v^- = v_{IN}$

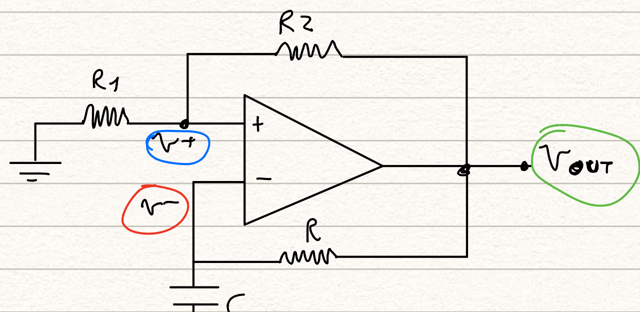
$$v^+ = \frac{R_1}{R_1+R_2} v_{OUT} + \frac{R_2}{R_1+R_2} V_{REF}$$

$$v_{IN} = \frac{R_1}{R_1+R_2} \underset{L^+ \quad L^-}{v_{OUT}} + \frac{R_2}{R_1+R_2} V_{REF}$$

GENERATORE DI FORMA D'ONDA QUADRA

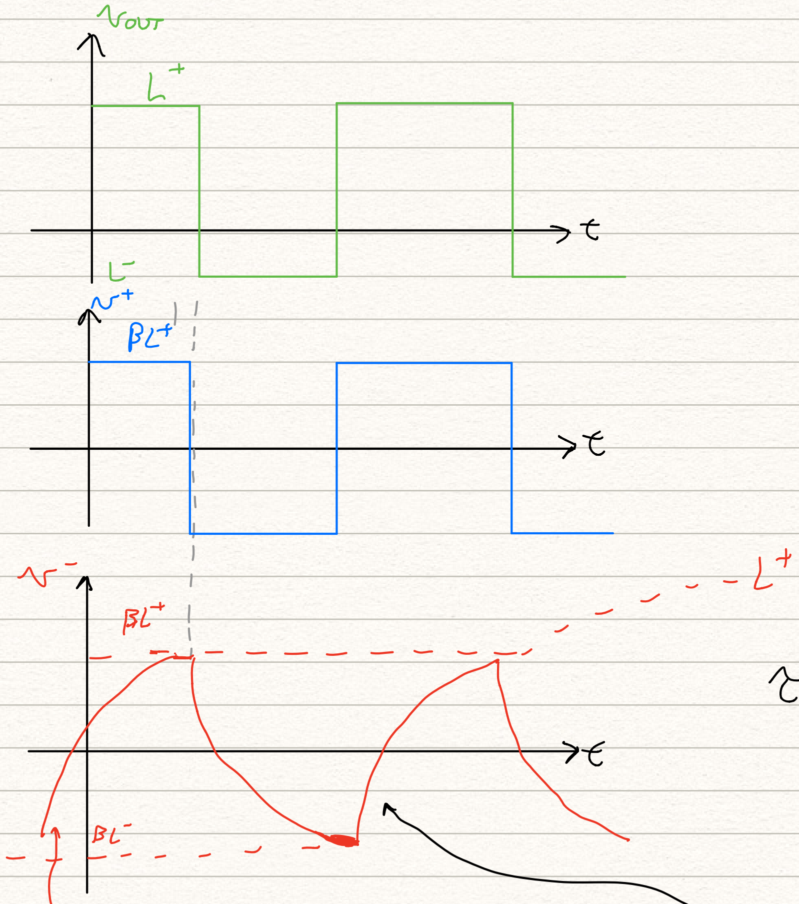
(MULTIVIBRATORE ASTABILE)





L^+

$$v^+ = \overbrace{\frac{R_1}{R_1+R_2}}^{\beta} v_{OUT} = \beta V_{OUT}$$



$\tau = RC$

esponenziale con costante di tempo τ $\quad v^- = L^+ - (L^+ - \beta L^-)\, e^{-t/\tau}$

$t = 0$

@ $t = T^+$ $\quad v^+ = \beta L^+$

$$\beta L^+ = L^+ - (L^+ - \beta L^-)\, e^{-T^+/\tau}$$

$$T^+ = \tau \ln \frac{1 - \beta (L^-/L^+)}{1 - \beta}$$

@ $T = T^-$ $\quad v^- = \beta L^-$

$$\beta L^- = L^- - (L^- - \beta L^+)\, e^{-T^-/\tau}$$

$$T^- = \tau \ln \frac{1 - \beta (L^+/L^-)}{1 - \beta}$$

assumed $\quad L^+ = -L^- = L > 0$

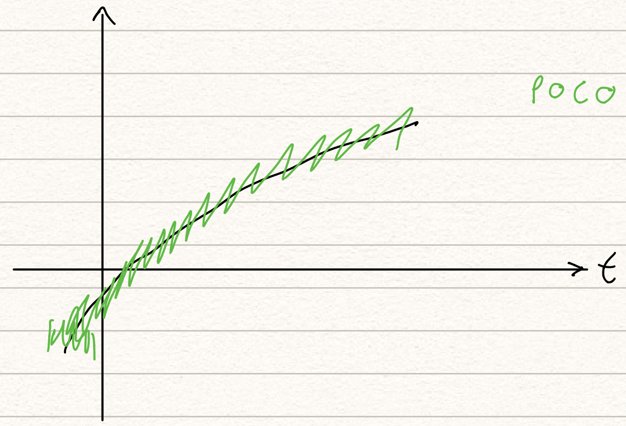
$$T^+ = \tau \ln \frac{1 + \beta}{1 - \beta}$$

$T^- = \tau \ln \quad 1 + \beta$

$$\frac{\quad}{1-\beta}$$

PERIODO

$$T = T^{+} + T^{-} = 2\tau \ln \frac{1+\beta}{1-\beta} \qquad \tau = RC$$



POCO PENDENTE

se scelgo β piccolo ho una maggiore pendenza

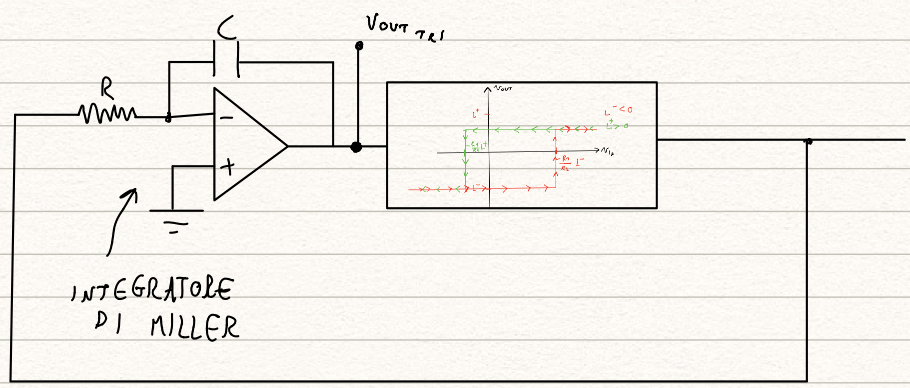
MOLTO PENDENTE

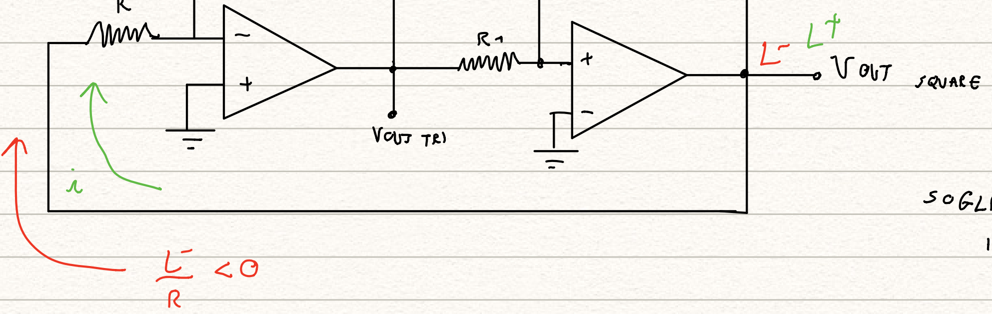
↓

meglio → MENO JITTER

"JITTER" = VARIAZIONE SUL PERIODO

GENERATORE DI ONDA QUADRA E TRIANGOLARE

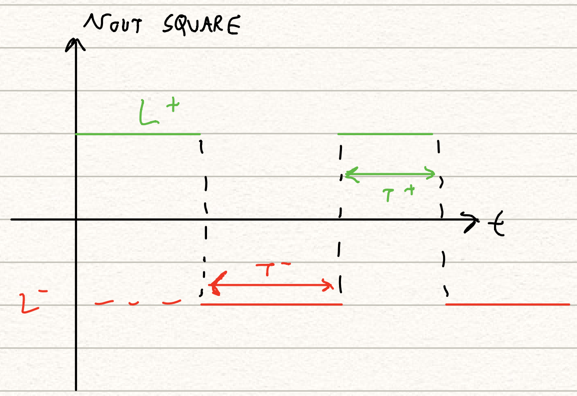


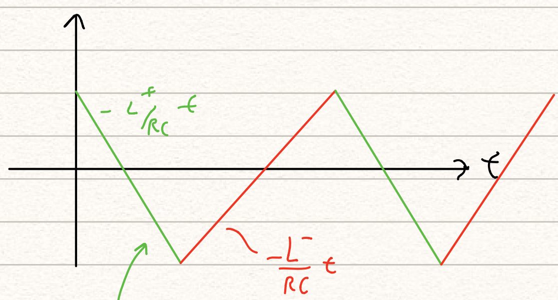


SOGLIE TRIGGER DI SCHMITT NON INVERTENTE

$$V_{TH}^+ = L^- \frac{R_1}{R_2}$$

$$V_{TH}^- = -L^+ \frac{R_1}{R_2}$$





$i = \frac{L^+}{R}$

$i = C \frac{dV}{dt}$

T^-:

$$-\frac{L^-}{RC} T^- = (V_{TH}^+ - V_{TH}^-) \qquad T^- = -\frac{RC}{L^-}\left(-L^- \frac{R_1}{R_2} + L^+ \frac{R_1}{R_2}\right) =$$

$L^+ = -L^-$

$$= RC \frac{\cancel{L} R_1/R_2 \cdot 2}{\cancel{L}}$$

?

T^+

$$-\frac{L^+ T^+}{RC} = (V_{TH}^- - V_{TH}^+)$$

$$T^+ = \frac{RC\left(-L^+ R_1/R_2 + L^- \frac{R_1}{R_2}\right)}{-L^+} =$$

$$= RC \frac{L R_1/R_2 \cdot 2}{-L}$$

$$T = T_1 + T_2 = 4RC\,\frac{R_1}{R_2}$$