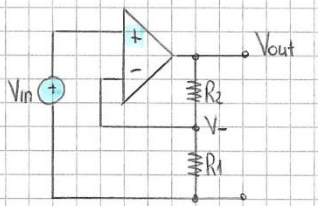
FORMULARIO

Amplificatore ideale

CONFIGURAZIONE NON INVERTENTE

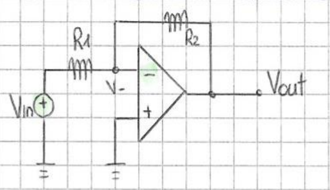


$$V_{in} = V_+ = V_- = V_{out}\frac{R_1}{R_1+R_2} = \beta V_{out}$$

$$\boxed{\beta = \frac{R_1}{R_1+R_2}}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\beta}$$

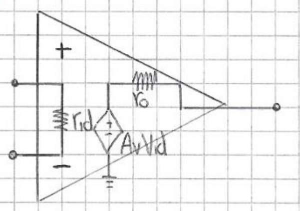
CONFIGURAZIONE INVERTENTE



$$\frac{V_{in}-V_-}{R_1} = \frac{V_- - V_{out}}{R_2} \quad e \quad V_- = V_+ = 0$$

$$\frac{V_{out}}{V_{in}} = 1 - \frac{1}{\beta}$$

Amplificatore reale



con $V_{id} = V_+ - V_-$

R_{if} : resistenza d'ingresso

R_{of} : resistenza d'uscita

con l'inserimento di: I_x, V_x $\quad R = \frac{V_x}{I_x}$

NON INVERTENTE $R_{if} = R_{id}(1+A_0\beta)$ $\quad R_{of} = \frac{R_o}{(1+A_0\beta)} \parallel (R_1+R_2)$

INVERTENTE $R_{if} = R_1 + \frac{R_2+R_o}{1+A_o} \parallel R_{id}$

Il guadagno è dipendente dalla frequenza $A = A(\omega)$ (dà il problema)

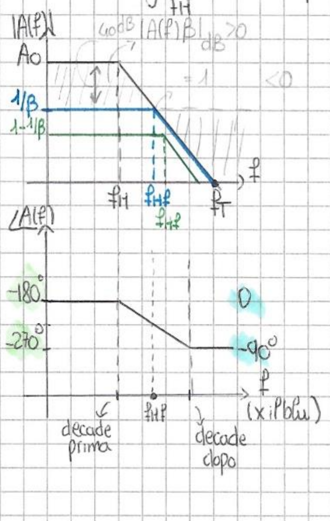
$$A_{fo} = \frac{1}{\beta}\frac{\beta A_o}{1+\beta A_o} \sim 1/\beta \qquad A_{fo} = \left(\frac{-1}{\beta}+1\right)\frac{\beta A_o}{1+\beta A_o} \sim 1-1/\beta$$

$$\boxed{\begin{array}{l} dB = 20\log(x) \\ x = 10^{dB/20} \end{array}}$$

$$A_f(f) = \frac{A_o}{1+j\frac{f}{f_H}}$$

A_o: guadagno in continua

f_H: frequenza di taglio a 3dB



f_T: freq di taglio (GBW) $\quad |A(f)| = 1 \sim \frac{A_o f_H}{f_T} = 1$

$|\beta A|$ guadagno ad anello

polo −20dB

zero +20dB

$$\frac{V_{out}}{V_{in}} = A(f) = A_{fo}\frac{1}{1+j\frac{f}{f_H(1+\beta A_o)}} \quad \text{(ricavato)}$$

$f_H(1+\beta A_o) = f_{Hf}$

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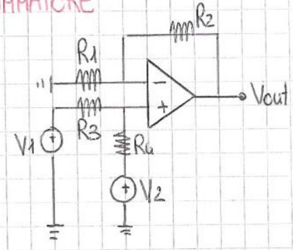
Ao con retroazione negativa

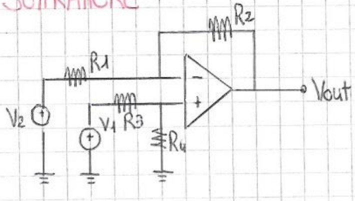
SOMMATORE



$$V_{out}(t)=\alpha_1 V_1(t)+\alpha_2 V_2(t)$$

con $\alpha_1=\left(1+\frac{R_2}{R_1}\right)\frac{R_4}{R_3+R_4}$ e $\alpha_2=\left(1+\frac{R_2}{R_1}\right)\frac{R_3}{R_3+R_4}$

SOTTRATTORE

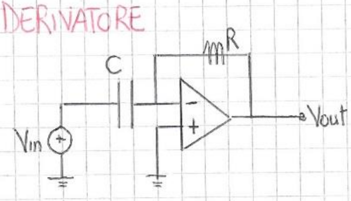


$$V_{out}(t)=\alpha_1 V_1(t)-\alpha_2 V_2(t)$$

$A_0=1/\beta$

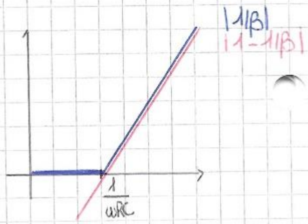
con $\alpha_1=\frac{R_4}{R_3+R_4}\,\frac{R_1+R_2}{R_1}$ $\quad\alpha_2=\frac{R_2}{R_1}$

DERIVATORE

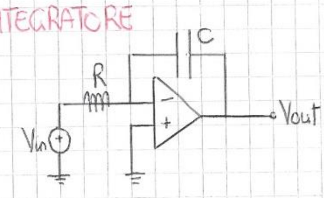


$$V_{out}(t)=-CR\frac{dV_{in}(t)}{dt}$$

- $\beta=\frac{1/j\omega C}{R+1/j\omega C}$
- $\frac{V_{out}}{V_{in}}=1-\frac{1}{\beta}$

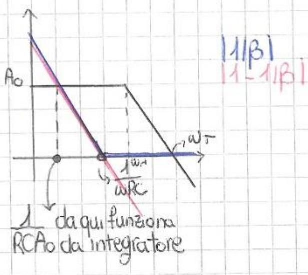


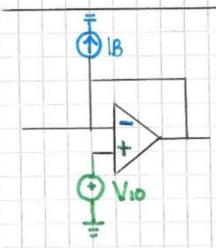
INTEGRATORE



$$V_{out}(t+t_0)=-\frac{1}{RC}\int_{t_0}^{t_0+t}V_{in}(\tau)d\tau+V_{out}(t_0)$$

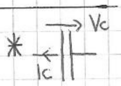
- $\beta=\frac{R}{R+1/j\omega C}$
- $\frac{V_{out}}{V_{in}}=1-\frac{1}{\beta}$





CORRENTE DI POLARIZZAZIONE ⊖

TENSIONE DI OFFSET ⊕

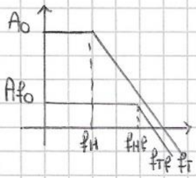


$$I_C=C\frac{dV_C(t)}{dt}$$

$$V_C(t)=\int_0^t\frac{I_C}{C}dt$$

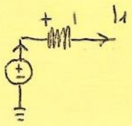
- Trova la funzione di trasferimento Vout/Vin
- tracciare i diagrammi di Bode di modulo e fase avendo $A(f) = \dfrac{A_0}{1+j\frac{f}{f_H}}$

=> devo trovare $A_{f0} \Rightarrow \underset{\text{es}}{1/\beta} \quad \dfrac{\beta A_0}{1+\beta A_0}$ guadagno

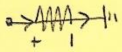


$f_{Hf} = f_H(1+\beta A_0)$ f. di taglio

$f_T: \quad \dfrac{A_0 \cdot f_H}{f_T} = 1$ f. di trasmissione (GBW)



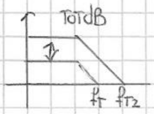
- Il generatore dà il verso della corrente
- per R, I va da + a -
- se ho solo una resistenza di solito va a mano



- Progettare... scegli il valore delle resistenze => sistema di equazioni

  + banda passante: ricalcola β $(f_{Hf} \geq \dots)$
  + SLEW RATE: $SR \geq \left|\dfrac{dV_{out}(t)}{dt}\right|_{MAX}$ (di solito $V_{out}(t) = V_0 \sin(2\pi f_0 t)$)

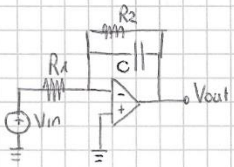
+ guadagno di anello



$f_{T2} = f_T \cdot T_0$ T0 assoluto

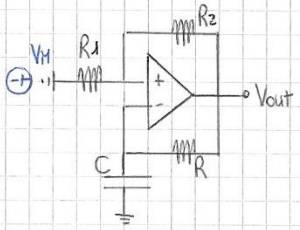
+ se ci chiede di valutare un amplificatore, devo guardare f_T

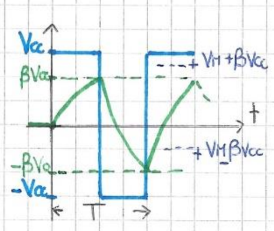
+ quando non mi viene dato il circuito



Ao con retroazione positiva

Multivibratore astabile



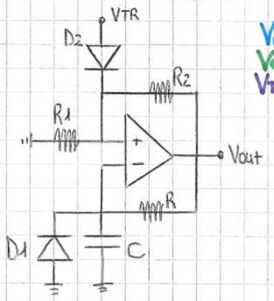


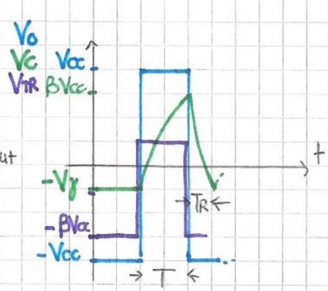
Vout
Vc

$$T = 2RC\ln\left(\frac{1+\beta}{1-\beta}\right)$$

$$* \; T_1 = RC\ln\left(\frac{1+\beta - V_M/V_{cc}}{1-\beta - V_M/V_{cc}}\right) \quad \left(\neq T_2 \quad \frac{1+\beta +}{1-\beta +}\right)$$

Multivibratore monostabile





$$T = RC\ln\left(\frac{1+V_\gamma/V_{cc}}{1-\beta}\right)$$

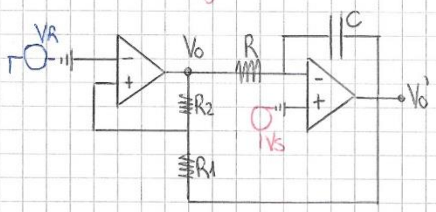
$$T_R = RC\ln\left(\frac{1+\beta}{1-V_\gamma/V_{cc}}\right)$$

D2

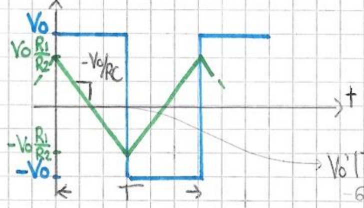
• per impulsi negativi

D1

Generatore di onda triangolare



$V_+ = 0$ commuta



Vo Vo'

$$T = 4RC\frac{R_1}{R_2}$$

$$V_o'(T/2) = V_o'(0) - \frac{V_o}{RC}\frac{T}{2}$$

* cambia la media

$$V_R + V_o\frac{R_1}{R_2}$$

$$V_R - V_o\frac{R_1}{R_2}$$

* cambiano i periodi

$$T_1 = \frac{2V_o}{V_o - V_s}\,\frac{R_1RC}{R_2} \qquad T_2 = \frac{2V_o}{V_o + V_s}\,\frac{R_1RC}{R_2}$$

Convertitori A/D e D/A

Generico

- massima frequenza del segnale in ingresso per rispettare il teorema del campionamento

$t_{campionamento} = t_{acquisizione} + t_{conversione}$

$f_C = \frac{1}{t_C}$ $\quad f_C \geq 2B \Rightarrow$ Trovo B

- massimo errore di quantizzazione

$V_{LSB} = \frac{V_{FS}}{2^n}$ $\quad$ n: bit

V_{FS}: fondoscala

• ARROTONDAMENTO $\left|\frac{V_{LSB}}{2}\right|$ $\quad$ • TRONCAMENTO

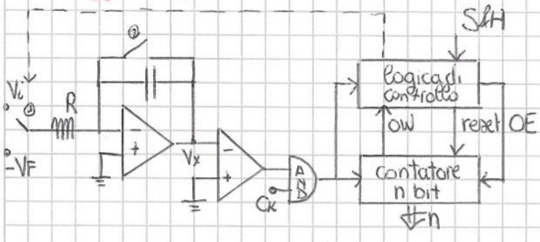
- massimo rapporto segnale-rumore

$SNR_{dB} = n \cdot 6{,}02 + 1{,}76$ (ARR) $\quad$ • half flash

$\qquad \qquad \quad - 4{,}25$ (TRONC) $\quad$ • a conteggio (doppia rampa) • SAR

A/D

a conteggio (doppia rampa)

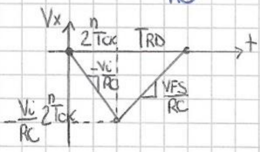


n bit, $V_i \in [0; V_{FS}]$

- $2^n T_{CK} = n T_{noise}$
- $V_{out} = -\frac{V_i}{RC} t_{noise}$

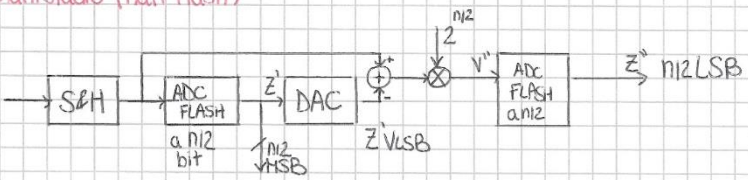
• $T_{conversione\ max} = 2 \cdot 2^n T_{CK}$

• RC: costante di tempo dell'integratore

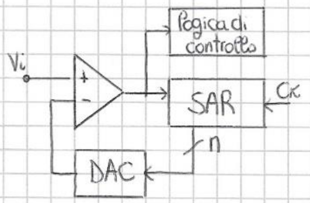


($T_C = t_{settling} + t_{acquisizione} + 2^n T_{CK} + n T_{noise}$) non sono sicura

multistadio (half flash)



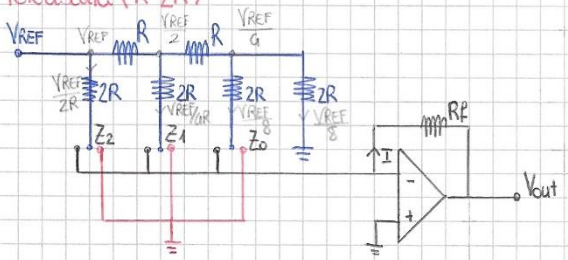
approssimazioni successive (SAR)



$T_{conversione} = n T_{CK}$

D/A

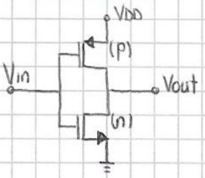
rete a scala (R-2R)



$$V_{out} = -I R_f \qquad I = \frac{V_{REF}}{2}\left[Z_2 + \frac{Z_1}{2} + \frac{Z_0}{4}\right]$$

$$\Rightarrow V_{out} = -\frac{V_{REF}}{8}\frac{R_f}{R}\left[4Z_2 + 2Z_1 + Z_0\right]$$

Invertez CMOS ⑤



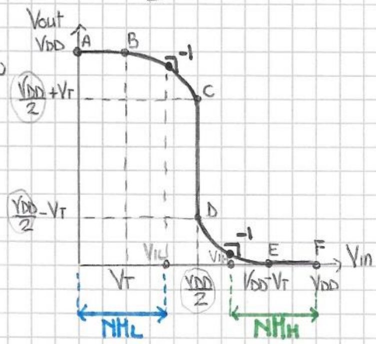
- $K_n = \frac{1}{2}\mu_n C_{ox}\frac{W_n}{L_n}$ $[A/V^2]$ con $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$

- tensione di soglia logica $K_n(V_i - V_{TN})^2 = K_p(V_{DD} - V_i - V_{TP})^2 \Rightarrow$ Trova V_i (V_{SL})

- tempo di propagazione $t_{P_{LH}} = \frac{\frac{V_{DD}}{2} \cdot C_L}{K_p(V_{DD} - V_{TP})^2}$ ($\cdot n$ se in serie) $\quad t_{P_{HL}} = \frac{\frac{V_{DD}}{2} \cdot C_L}{K_n(V_{DD} - V_{TN})^2}$ ($\cdot n$ in serie)

$$t_P = \frac{t_{P_{LH}} + t_{P_{HL}}}{2}$$

- Caratteristica di trasferimento



- V_{SL}

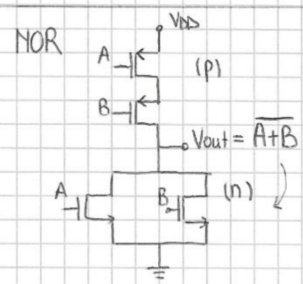
- Margini di rumore $NM_H = V_{DD} - V_{IHmin} = NM_L$

- Potenza dissipata dinamica $P_D = N\, C_L V_{DD}^2 f$

- Corrente di picco ($V_i = V_{DD}/2$) $I_P = K_n(V_i - V_{TN})^2$

statica (equiprobabile) $P_D = \frac{1}{2} V_{DD} I_D$

NOR

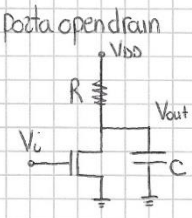


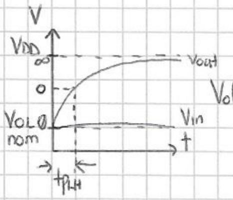
- p e n sono "simmetrici", prima si fa n, e poi p

+ : in parallelo

$\cdot$: in serie

porta open drain





$$V_o(t_{P_{LH}}) = \frac{V_{DD} + V_{OL}}{2}$$

$$V_o(t) = [V_o(\infty) - V_o(0)](1 - e^{-t/RC}) + V_o(0)$$

oscillatore ad anello

$T = (t_{pLH} + t_{pHL}) \cdot N$

Memoria