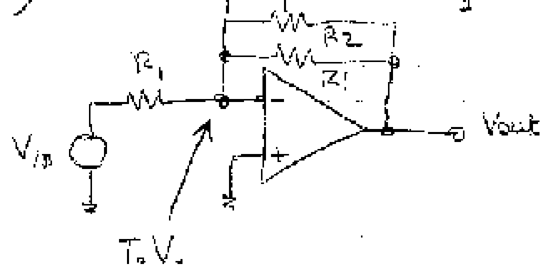
ES. A

1) ad alte frequenze C_1 è un corto circuito



$$G_{HF} = \frac{V_{out}}{V_{in}}\bigg|_{HF} = -\frac{R_1 /\!/ R_2}{R_1} = -\frac{R_1 R_2}{R_1+R_2}\cdot\frac{1}{R_1} = -\frac{R_2}{R_1+R_2} = -\frac{10}{11}$$

2) $$G(s) = \frac{V_{out}}{V_{in}}(s) = -\frac{Z_2(s)}{Z_1(s)} = -R_2\frac{(1+sC_1R_1)}{1+sC_1(R_1+R_2)}\cdot\frac{sC_1}{1+sC_1R_1} = -\frac{sC_1R_2}{1+sC_1(R_1+R_2)}$$

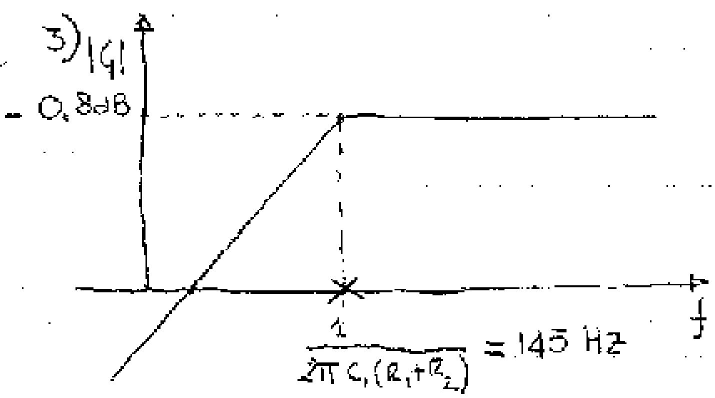
$$Z_2(s) = \left(R_1 + \frac{1}{sC_1}\right) /\!/ R_2 = \frac{1+sC_1R_1}{sC_1} /\!/ R_2 =$$

$$= \frac{R_2}{sC_1}(1+sC_1R_1) \Big/ \left(\frac{1+sC_1R_1}{sC_1} + R_2\right) =$$

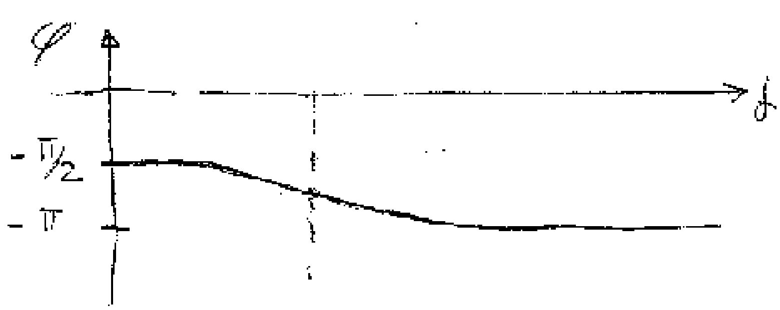
$$= \frac{R_2}{sC_1}\,\frac{(1+sC_1R_1)}{1+sC_1(R_1+R_2)}\, sC_1$$

$$Z_1(s) = R_1 + \frac{1}{sC_1} = \frac{1+sC_1R_1}{sC_1}$$

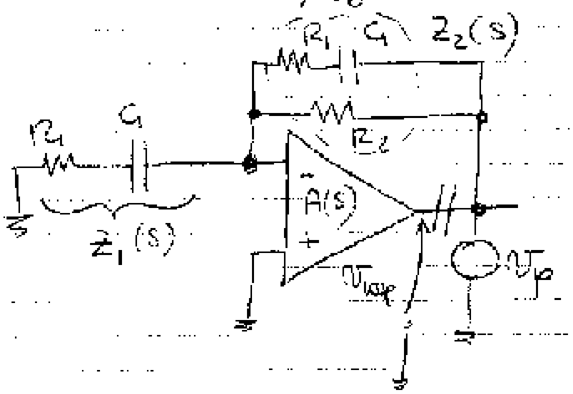
3)



FILTRO PASSA-ALTO



4) $A(s) = \dfrac{A_0}{1 + s/\omega_0}$ $\qquad A_0 = 100\,dB \qquad \omega_0 = 10\ rad/s$



$$G_{loop}(s) = -\frac{Z_1(s)}{Z_1(s) + Z_2(s)} \cdot A(s) =$$

$$= -\frac{1+sC_1R_1}{sC_1} \cdot \frac{1}{\dfrac{1+sC_1R_1}{sC_1} + R_2\dfrac{(1+sC_1R_1)}{1+sC_1(R_1+R_2)}} \cdot \frac{A_0}{1+\frac{s}{\omega_0}} =$$

$$= -\frac{1}{sC_1\left[\dfrac{1+sC_1(R_1+R_2)+sC_1R_2}{sC_1\,(1+sC_1(R_1+R_2))}\right]} \cdot \frac{A_0}{1+\frac{s}{\omega_0}} =$$

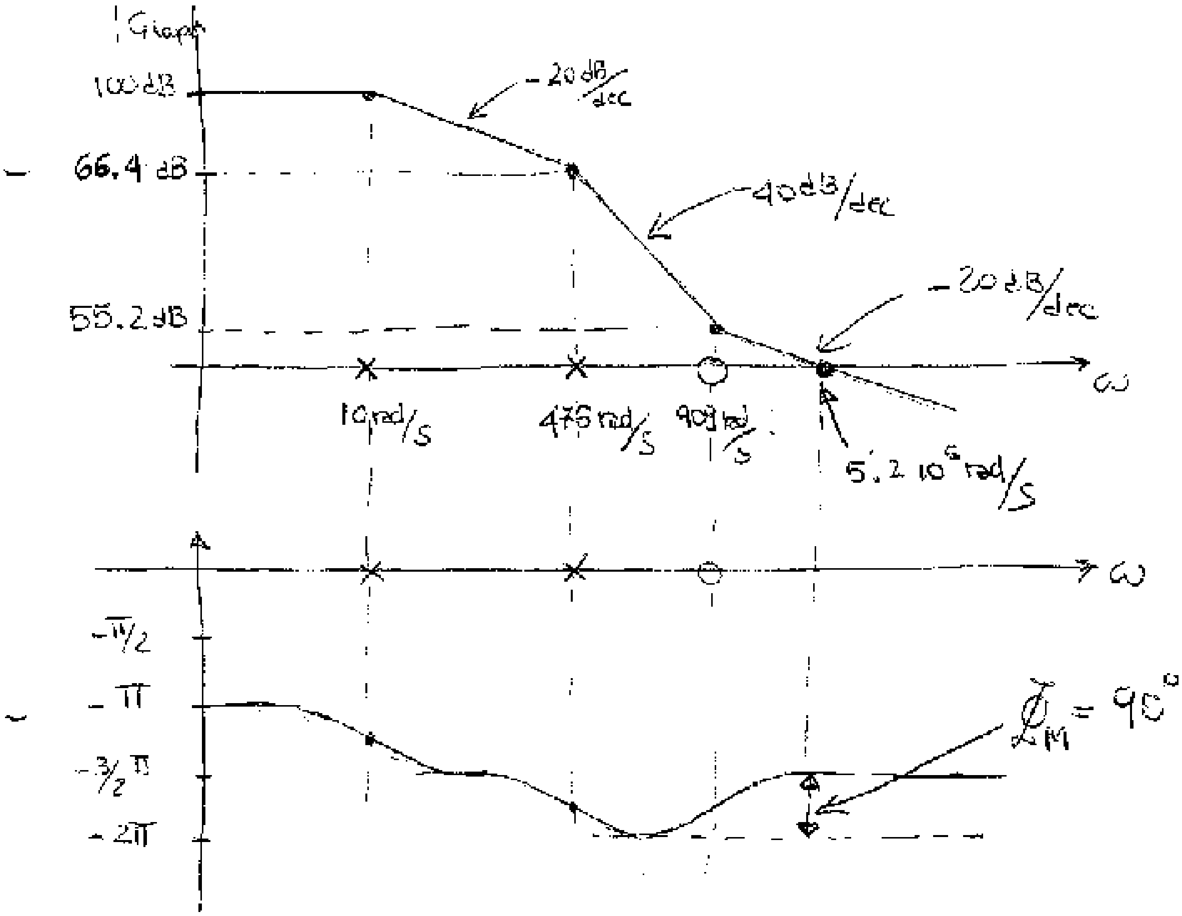
$$= -\frac{1+sC_1(R_1+R_2)}{1+sC_1(R_1+2R_2)} \quad \frac{A_0}{1+s/\omega_0}$$

$\tau_z = C_1\,(R_1+R_2) = 1.1\ ms \Rightarrow f_z = 145\ Hz \qquad \omega_z = 909\ rad/s$

$\tau_p = C_1\,(R_1+2R_2) = 2.1\ ms \Rightarrow f_p = 76\ Hz \qquad \omega_p = 476\ rad/s$

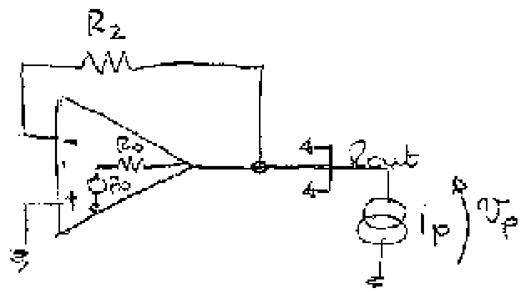
$f_{p_1} = 15.7\ Hz \Leftarrow \omega_0 = 10\ rad/s$

$|G_{loop}(0)| = |A_0| = 100\ dB$



Il circuito è sufficientemente stabile poiché ha un margine di fase di 90°.

5)



$$R_{out} = \frac{v_p}{i_p} \xrightarrow{A_0 \to \infty} 0$$

$$\Downarrow$$

$$R_{out} = \frac{R^{\circ}_{out}}{1 - G_{loop}(0)}$$

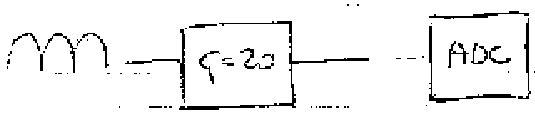
$$\left.\begin{aligned} G_{loop}(0) &= -A_0 \\ R^{\circ}_{out} &= R_0 \end{aligned}\right\} \Rightarrow R^{\circ}_{out} = \frac{R_0}{1 + A_0} = \frac{100\,\Omega}{10^5} = 1\,m\Omega$$

ES. B

1) $V_{in}\Big|_{MAX} = 250\,mV$ $\quad V_{FS}\Big|_{ADC} = 5V$

$$G_{ampl} = \frac{5V}{250mV} = 20 = 1 + \frac{R_2}{R_1}$$

2)



$$\frac{1}{1000} \cdot 250mV = 250\,\mu V$$

↳ $1LSB = \frac{V_{FS}}{2^n}$

$1LSB = 250\mu V * 20 = 5mV$

$$5 \cdot 10^{-3} = \frac{5}{2^n}$$

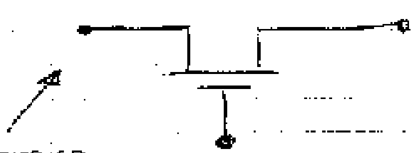
⇓

$$n \geq \log_2 1000 \cong 10$$

⇓

$$1LSB\Big|_{IN} = \frac{5V}{2^{10}} \frac{1}{20} = 244\,\mu V$$

3)



dinamica segnale

$0 \div 5V$

N-MOS on $\begin{cases} V_{GS} > V_{TN} \\ (V_{GD} < V_{TN}) \end{cases}$

↳ $V_{GS} > 1V \Rightarrow V_G > V_{S_{MAX}} + 1V = 6V$

$$R_{ds}\Big|_{on} = \frac{1}{2k(V_{GS}-V_{TN}) - 2kV_{DS}}\Bigg|_{V_{DS}=0} = \frac{1}{2k(V_{GS}-V_{TN})}$$

$$↳ V_{GS} = V_{TN} + \frac{1}{2k\,R_{DS_{on}}} = 1V + \frac{1}{2mA/V^2 * 2 * 50\Omega} = 6V$$

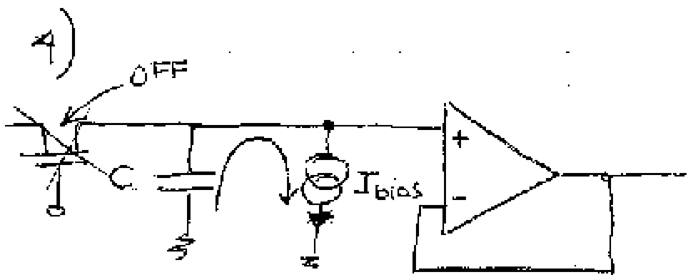
⇓ $V_G \geq 6V + V_{S_{MAX}} = 6V + 5V = 11V$ FASE DI SAMPLE

FASE DI HOLD: N-MOS OFF $\Big\{\; V_{GS} < V_{TN}$

$V_{GS} < 1V \Rightarrow V_G < 1V + V_{S_{MIN}} = 1V$

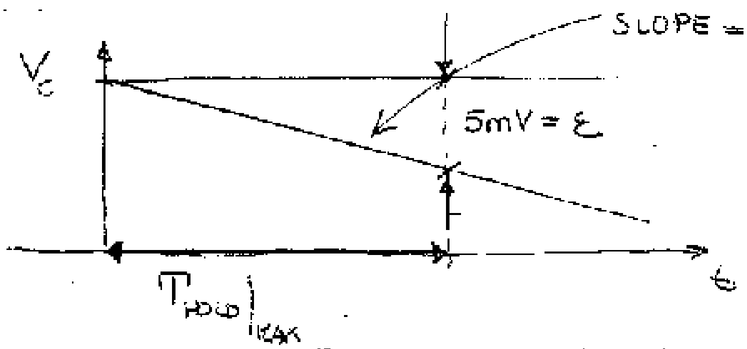
↳ ad esempio posso scegliere $V_G = -2V$.

4)



assegno arbitrariamente un verso alla I_{bias} per comodità nei grafici/calcoli

MASSIMA DINAMICA $= 5V \Rightarrow$ droop massimo ammesso $\frac{5V}{1000} = 5mV$



$$T_{HOLD}|_{MAX} = \frac{C \times \varepsilon}{I_{bias}} = \frac{100\,nF \times 5mV}{1\mu A} = 500\mu s$$

5) $V_{out_2} = V_C \left(\frac{1}{1 - 1/G_{loop}(0)} \right)$

↑ Tensione ai capi della capacità

⇓

$\varepsilon = \left| \frac{1}{G_{loop}(0)} \right| = \frac{1}{A_0} \Rightarrow \quad A_0 \geq \frac{1}{\varepsilon} = 10^3 = 60\,dB$

↑ ERRORE DI GUADAGNO

6) $\left. \begin{array}{l} f_{CK} = 1MHz \\ T_{HOLD} = 100\mu s \end{array} \right\} \Rightarrow T_{CONV} < T_{HOLD}$

↓

$T_{CONV} < 100\mu s$

FLASH ADC : $T_{CONV} = \frac{1}{f_{ck}} = 1 \mu s$

ADC A GRADINATA : $T_{CONV} = \frac{2^n}{f_{ck}} = \frac{2^{10}}{1 MHz} = 1.02 ms$

ADC AD APPROSSIMAZIONI SUCCESSIVE : $T_{CONV} = \frac{n}{f_{ck}} = \frac{10}{1 MHz} = 10 \mu s$

⇓

L'ADC più adatto è quello ad approssimazioni successive