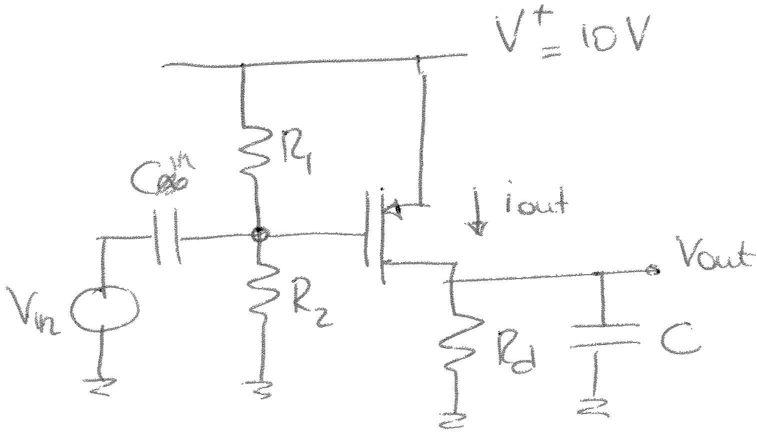
FONDAMENTI DI ELETTRONICA – APPELLO 21 LUGLIO 2010

ES 1



$R_1 = 200\,k\Omega$
$R_2 = 800\,k\Omega$
$R_d = 6\,k\Omega$
$|V_{Tp}| = 1V$
$|k_p| = 1mA/V^2$
$C_{in} = 4.7\,\mu F$

a. POLARIZZAZIONE

Hp MOS saturo

C, C_{in} circuiti aperti

V_{in} spento

$$V_{GS} = -\frac{R_1}{R_1+R_2}V^+ = -\frac{200\,k\Omega}{1000\,k\Omega}\,10V = -2V < V_{Tp} \rightarrow \text{MOS on}$$

$\Downarrow$

$$I_D = |k_p|\,(V_{GS}-V_{Tp})^2 = 1mA/V^2\,(-2V+1V)^2 = 1mA$$

$\hookrightarrow V_D = I R_d = V_{out} = 1mA * 6k\Omega = 6V$

$\hookrightarrow V_{GD} = 10V - 2V - 6V = +2V > V_{Tp}$ ok MOS saturo

$$g_m = 2|k_p(V_{GS}-V_{Tp})| = 2 * 1mA/V^2 * |(-2V+1V)| = 2mA/V \rightarrow 1/g_m = 500\,\Omega$$

b. $\left.\frac{v_{out}}{v_{in}}\right|_{LF}$

$$v_{out} = -i_d R_d = -g_m v_{in} R_d \rightarrow \frac{v_{out}}{v_{in}} = -g_m R_d = -2*6 = -12$$

c. diagramma di Bode

$\frac{v_{out}}{v_{in}}$: C inserisce un polo con $\tau_p = C R_d = 100pF * 6k\Omega = 600\,ns$

$\hookrightarrow f_p = \frac{1}{2\pi\tau_p} = 265\,kHz$

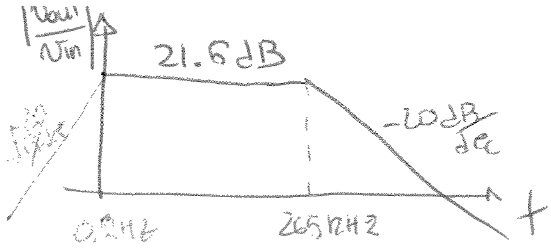
e nessuno zero al finito

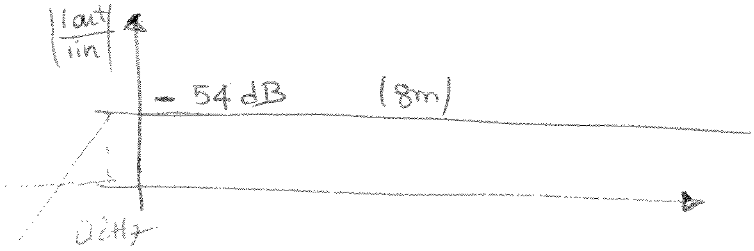
C_{in}: zero nell'origine

$\tau_{in} = C_{in}(R_1 /\!/ R_2) = 752\,ms$

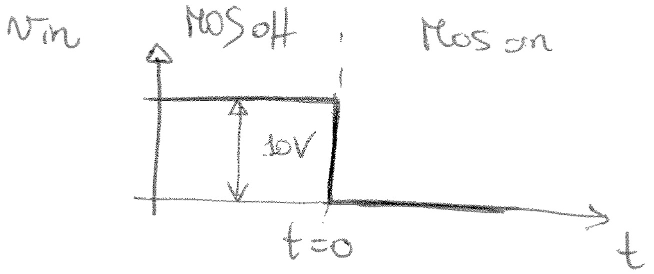
$\hookrightarrow f_p = \frac{1}{2\pi\tau_{in}} = 0.2\,Hz$

$\frac{i_{out}}{v_{in}}$: C non introduce nè poli nè zeri





d.



at $t=0^+$ $V_{GS_p} = -10V \Rightarrow$ MOS on

La capacità è inizialmente scarica $\Rightarrow V_{out}=0$

$\Downarrow$ pMOS saturo.

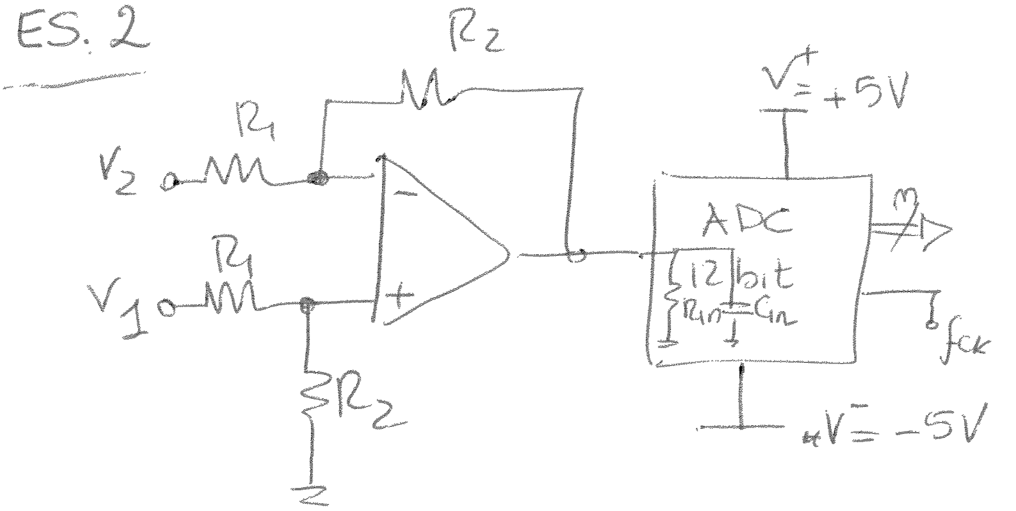
$$\frac{dV_{out}}{dt} = \frac{I}{C}$$ e la corrente nel pMOS è la corrente di saturazione

$$I = k_p(V_{GS}-V_{T_p})^2 = 1mA/V^2\,(-10V+1V)^2 = 81\,mA$$

$\Downarrow$

$$\frac{dV_{out}}{dt} = \frac{81mA}{0.1nF} = 810\,V/\mu s$$

ES. 2



$C_{in} = 2pF$
$R_{in} = 50\,\Omega$
$R_1 = 1k\Omega$
$R_2 = 20k\Omega$

a. $v_{out}/(v_2 - v_1)$
Sovrapposizione degli effetti

$$v^+_{v_1} = \frac{R_2}{R_1+R_2} v_1$$

$$v_{out}\Big|_{v_1} = \left(1+\frac{R_2}{R_1}\right) v^+_{v_1} = \left(1+\frac{R_2}{R_1}\right)\frac{R_2}{R_1+R_2} v_1 = \frac{R_2}{R_1} v_1$$

$$v_{out}\Big|_{v_2} = -\frac{R_2}{R_1} v_2 \Rightarrow v_{out} = v_{out}\Big|_{v_1} + v_{out}\Big|_{v_2} = -\frac{R_2}{R_1}(v_2 - v_1)$$

$$\hookrightarrow \frac{v_{out}}{v_2 - v_1} = -\frac{R_2}{R_1} = -20$$

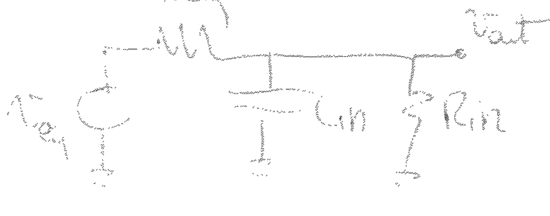
b. $(v_2 - v_1)\Big|_{MAX}$ è tale che $FSR = -20\,(v_2 - v_1)\Big|_{MAX}$

$$\hookrightarrow (v_2 - v_1)\Big|_{MAX} = \frac{1}{2}\left|\frac{FSR}{-20}\right| = \frac{1}{2}\frac{10V}{20} = \frac{500mV}{2} = 250mV$$

Risoluzione in ingresso:

$$Ris_{in} = \frac{1LSB}{G_{diff}} = \frac{FSR}{2^m \cdot G_{diff}} = \frac{10V}{2^{12} \cdot 20} = 122\,\mu V$$

c. Posso modellizzare l'amplificatore differenziale con il suo equivalente Thevenin



$$R_{eq} = \frac{r_o /\!/ (R_2+R_1)}{1 - G_{loop}(0)} \simeq \frac{100\,\Omega}{120.6} = 0.836\,\Omega$$

$$G_{loop} = -\frac{R_1}{R_1+R_2} A_0 = -\frac{1k}{21k} \cdot 2512 = 119.6$$

c. $V_{eq} = G_{eff\,reale}\,(V_2 - V_1) \Rightarrow$ $1.93\,V$ ✓

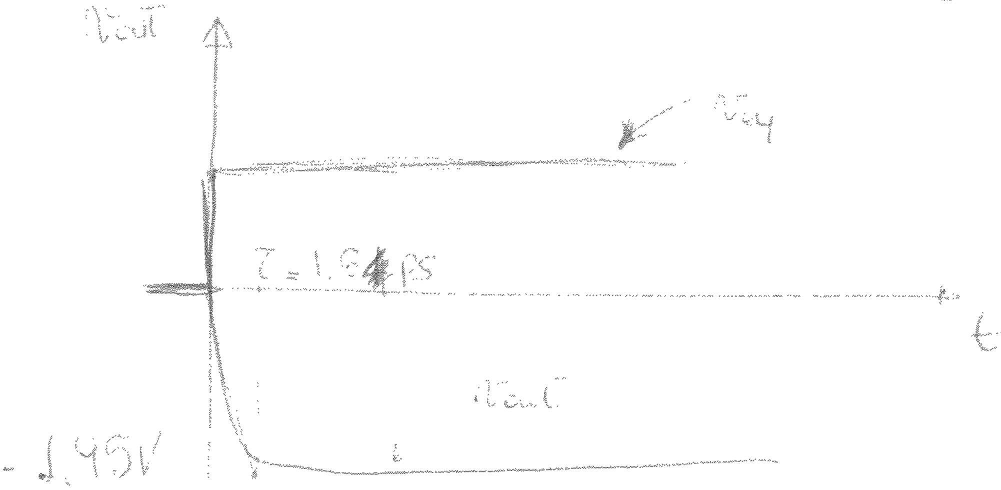
$$G_{eff\,reale} = \frac{G_{eff\,ideale}}{1 - \frac{1}{G_{loop}}} = \frac{-\frac{R_2}{R_1}}{1 + \frac{1}{12.6}} = -14.83$$

$$\tau_{eq} = C_{in}\,(R_{in} \parallel R_{eq}) = 2pF * 0.82 = 1.64\,ps$$

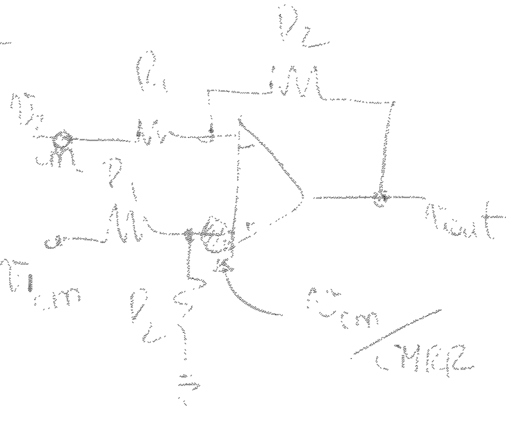
0.483

$$V_{out}\Big|_{regime} = V_{eq}\Big|_{regime}\,\frac{R_{in}}{R_{in} + R_{eq}} \simeq V_{eq}\Big|_{regime}$$

$\hookrightarrow = 1.95\,V$ ✓



d.



Calcolo V_{cm} sotto le hp di opamp ideale con la sovrapposizione degli effetti.

$$V_{cm} = 0 + \frac{V^+ + V^-}{2} \cong V^+ = \frac{R_2}{R_1 + R_2}\,V_{cm}^{-}$$

contesto diff.

$$= \frac{20}{21} * 1V = 0.952\,V$$ ✓

$$\hookrightarrow V_{out}\Big|_{cm} = \frac{V_{cm}}{CMRR}\left(1 + \frac{R_2}{R_1}\right)$$

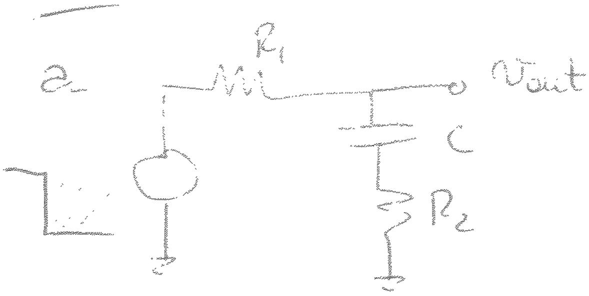
$$1\,LSB = \frac{10V}{4096} = 2.44\,mV$$ ✓

$$\frac{V_{cm}}{CMRR}\left(1 + \frac{R_2}{R_1}\right) < 1.5\,LSB$$

$$\hookrightarrow CMRR > V_{cm}\,\frac{\left(1 + \frac{R_2}{R_1}\right)}{1.5\,LSB} = 0.952V * \frac{21}{1.5 * 2.44\,mV} = 5462 \simeq 75\,dB$$

ES. 3

a.



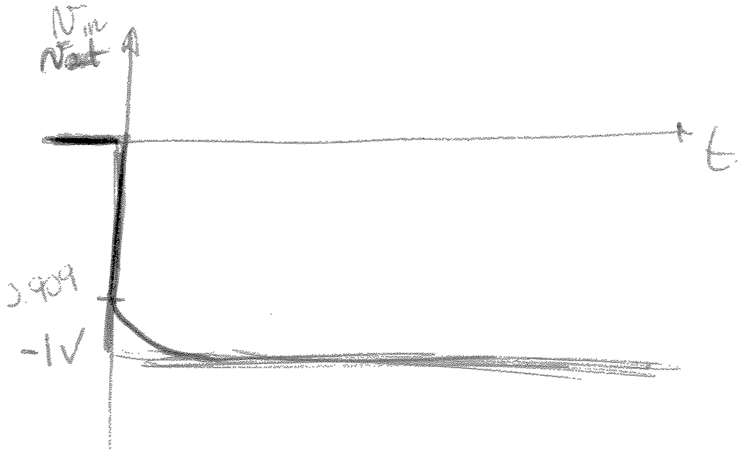
$$\tau = C(R_1+R_2) = 1nF(5.5k\Omega) = $$
$$= 5.5\,\mu s$$

$$v_{out}\Big|_{regime} = v_{in}\Big|_{regime}$$

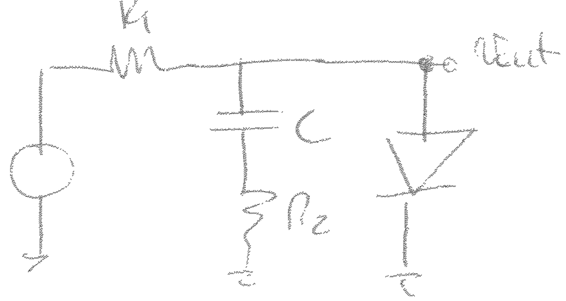
$$v_{out}\Big|_{fronte} = v_{in}\Big|_{fronte}\frac{R_2}{R_1+R_2} =$$

$$= 1V * \frac{5k}{5.5k} = \frac{10}{11}V =$$

$$= 0.909\,V$$



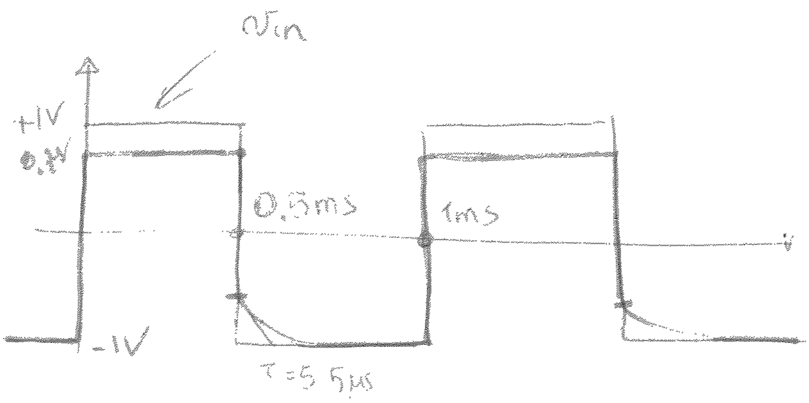
b.



$$T = 1ms \Rightarrow \frac{T}{2} \gg \tau$$

Lo vede a regime entro ogni semiperiodo

- semiperiodo negativo: $D_{off} \Rightarrow v_{out}\big|_{regime} = v_{in}\big|_{regime}$
- semiperiodo positivo: $D_{on} \rightarrow v_{out}\big|_{regime} = 0.7V$

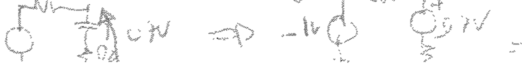


Fronte positivo → il segnale farebbe un salto pari a

$$2V * \frac{R_2}{R_1+R_2} = 1.81V \rightarrow \text{arriverebbe a } +0.81V > 0.7V$$

il diodo si accende istantaneamente → il fronte è tutto istantaneo

Appena v_{in} ha il fronte negativo il diodo si spegne.

 $\Rightarrow v_{out} = 0.7V * \frac{R_1}{R_1+R_2} - 1V\frac{R_2}{R_1+R_2} = -0.845V$

2 Senza in assenza di S&H

$$\frac{d\, v_{in}|_{MAX}}{dt} \cdot T_{conv} < 0.5\,LSB$$

$$\left.\frac{d\, v_{in\,MAX}}{dt}\right|_{max} = A\,\omega$$

$$T_{conv} = \frac{2^n}{f_{ck}}$$

$$\left\{\begin{array}{l} A \cdot 2\pi \cdot f \cdot \dfrac{2^n}{f_{ck}} < 0.5\,LSB \\[2ex] \dfrac{\cancel{FSR}}{\cancel{2}} \cdot \cancel{2}\pi \cdot f \cdot \dfrac{2^n}{f_{ck}} < \dfrac{\cancel{FSR}}{2^{n+1}} \end{array}\right.$$

$$f < f_{ck}\, \frac{1}{2^{n+1} \cdot 2^n \cdot \pi} = 10\,MHz\, \frac{1}{2^{25} \cdot \pi}$$

$$= 95\, mHz \;!!$$