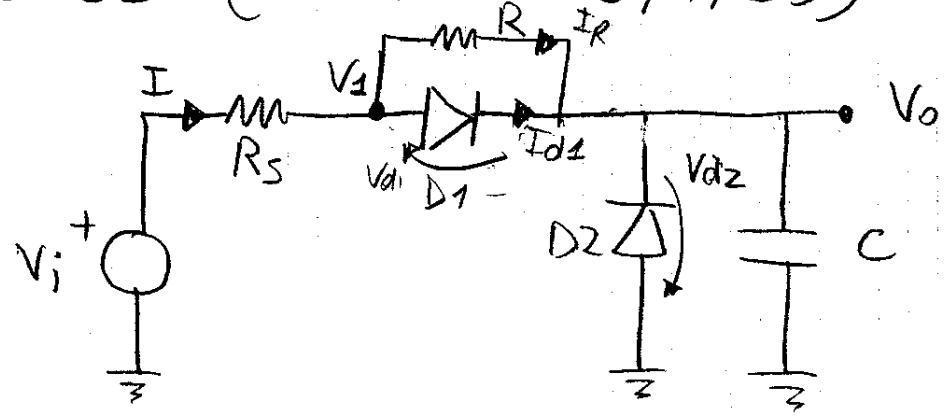
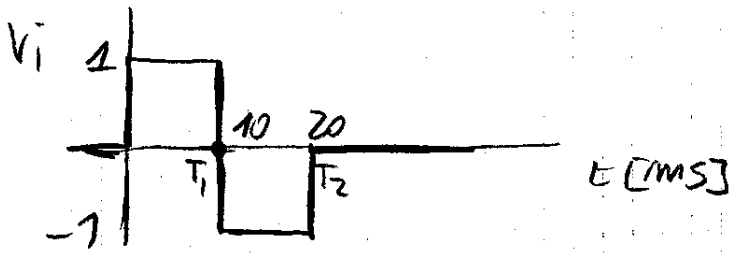
• ES (SCRITTO 25/7/95)



$R = 1\,M\Omega$
$R_S = 100\,k\Omega$
$C = 1\,nF$



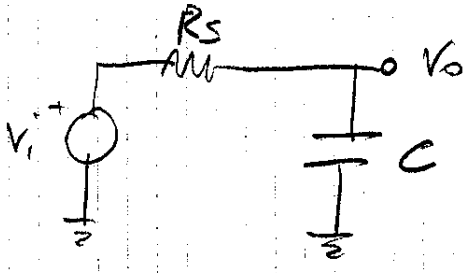
C scarico per $t = 0$

? $V_o(t)$? per: ① $V_\gamma = 0\,V$ ② $V_\gamma = 0.7\,V$

① $V_\gamma = 0\,V$

$0 < t < T_1$

$V_i = 1\,V$ D1 ON D2 OFF

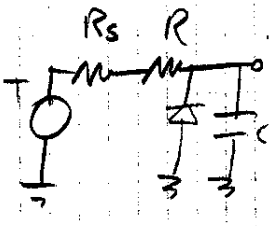


$V_o(t) = 1\,(1 - e^{-t/\tau_1})$

$\tau_1 = R_S C = 10^5 \cdot 10^{-9} = 10^{-4}\,s = 0.1\,ms$

$T_1 < t < T_2$

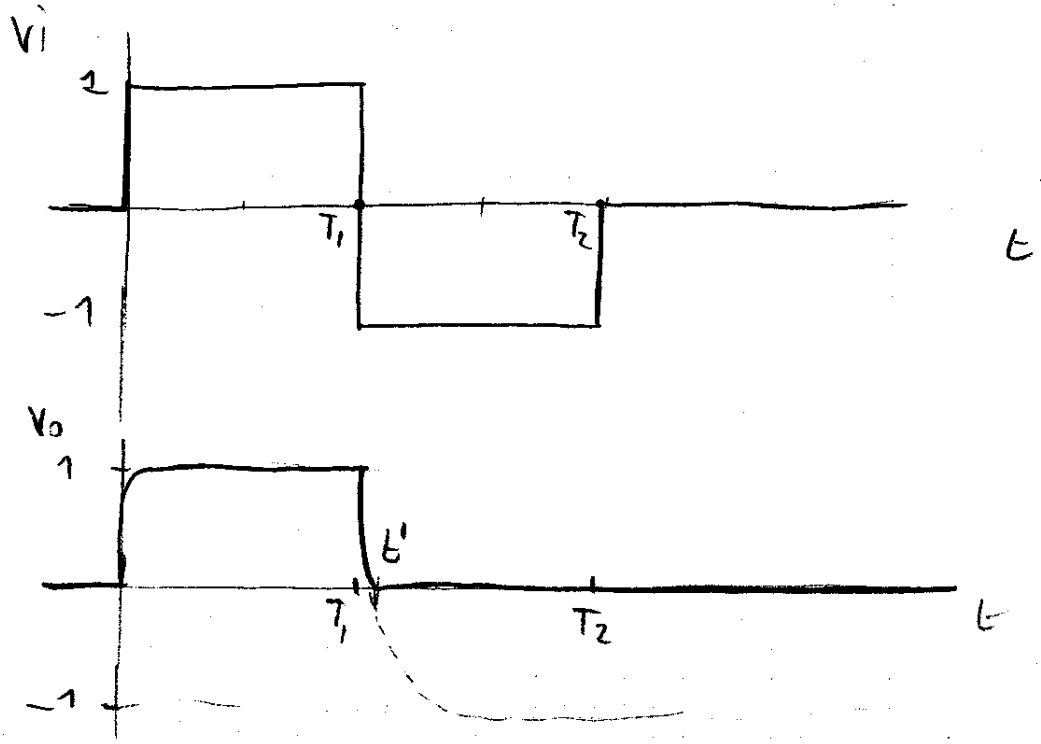
$V_i = -1\,V$ D1 OFF D2 OFF (iniz.)



$V_o(t)$: Tenderebbe a -1 con exp.
$(\tau_2 = (R_S + R)C = 1.1 \cdot 10^5 \cdot 10^{-9} = 1.1\,ms$

$V_o(t') = 0$: D2 ON

$t > T_2$ $V_i = 0$: D1 OFF D2 OFF



② $V_\gamma = 0.7\ V$

$\boxed{0 < t < T_1}$ $V_i = 1\ V$

D2 OFF
D1 ?

* Avere D1 ON ci vuole caduta di 0.7 V su D1 – C si carica, I diminu-

Condiz. per D1 ON : $I_{d1} > 0$
(è cond. su v_o)

$$I_{d1} = I - I_R$$

$$I = \frac{V_i - V_1}{R_S} = \frac{V_i - (V_o + V_\gamma)}{R_S} = \frac{V_i - V_o - V_\gamma}{R_S}$$

$$I_R = \frac{V_\gamma}{R}$$

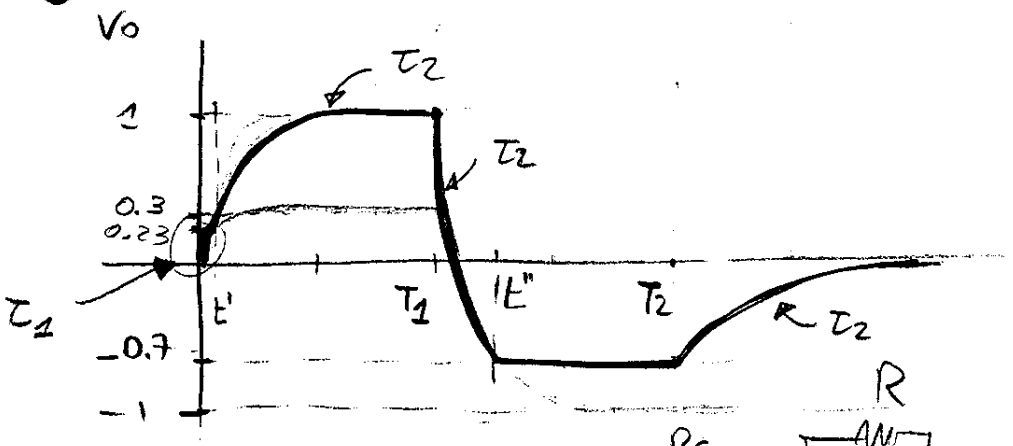
$$I_{d1} = \frac{V_i}{R_S} - \frac{V_o}{R_S} - \frac{V_\gamma}{R_S} - \frac{V_\gamma}{R} > 0$$

$$\frac{V_o}{R_S} < \frac{V_i}{R_S} - \frac{V_\gamma}{R_S} - \frac{V_\gamma}{R}$$

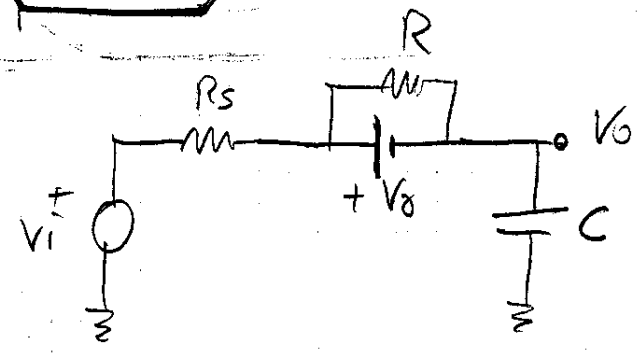
$$V_o < V_i - V_\gamma\left(1 + \frac{R_S}{R}\right) = 1 - 0.7 \cdot 1.1 = 1 - 0.77 = +0.23\ V$$

$0 < V_0 < 0.23$ V D1 ON

$V_0 > 0.23$ V D1 OFF



D1 ON:



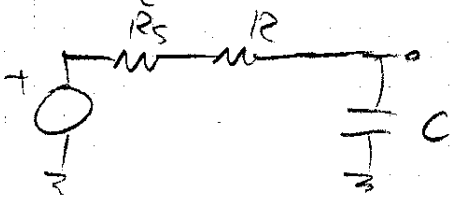
Vo: andam. esp.

- Val. asintotico: $V^* = V_i - V_\gamma = +0.3$ V
- $\tau_1 = R_S C = 0.1$ ms

Quest'andam. finisce a t' ($V_0(t') = 0.23$ V)

!! NON È POSSIB. VAL. DI REGIME $V_0 = 0.3$ V !!

$t > t'$: D1 OFF

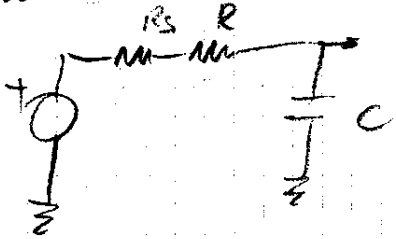


Vo: andam. esp.

- Val. asint.: $V_i = +1$ V
- $\tau_2 = (R_S + R) C = 1.1$ ms

$t > T_1$ D1 OFF

D2 OFF (INIZ.)



Vo: andam. esp

- Val. asint = $V_i = -1$ V
- $\tau_2 = 1.1$ ms

$t = t''$: D2 ON ($V_0(t'') = -V_\gamma = -0.7$ V)

$t > t''$: $V_0(t) = -0.7$

$t > T_2$ $\quad V_i = 0\ V$

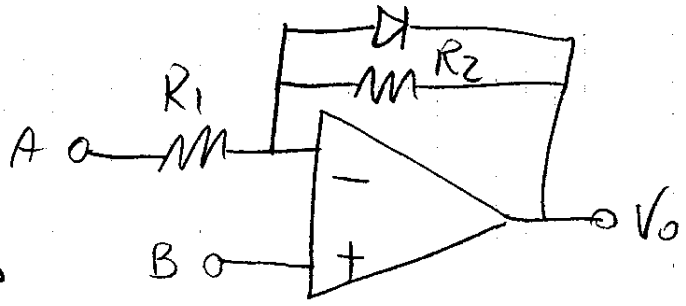
D1 OFF
D2 OFF

V_0: e+p
- Valassint: $V_i = 0V$
- $T_2 = 1.1\ ms$

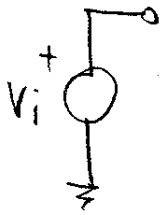
OSSERVAZIONE:

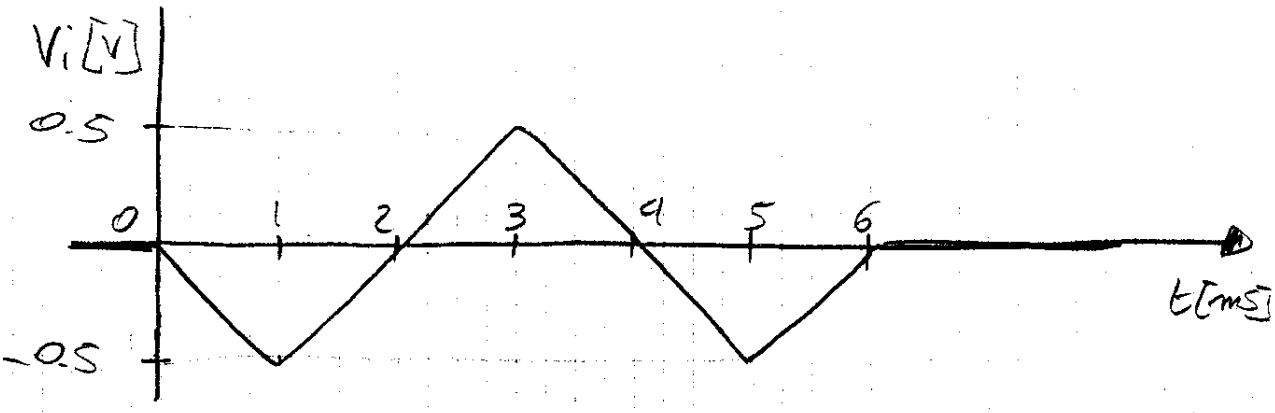
- Differenza tra i casi ① e ②:
è nel comportam. di D1 —
Caso ①: basta $V_i > V_0$ per avere D1 ON
Caso ②: ($V_\gamma = 0.7$) Accensione D1 dipende da I_{D1} → dipende da V_0.
$t = 0^+$: D1 ON
Durata accensione: dip. da R_S, R
! Non possibile $V_0 = 0.3$ come val. di regime !

ES DIODI + AO (DIODI IN REAZ.) 37

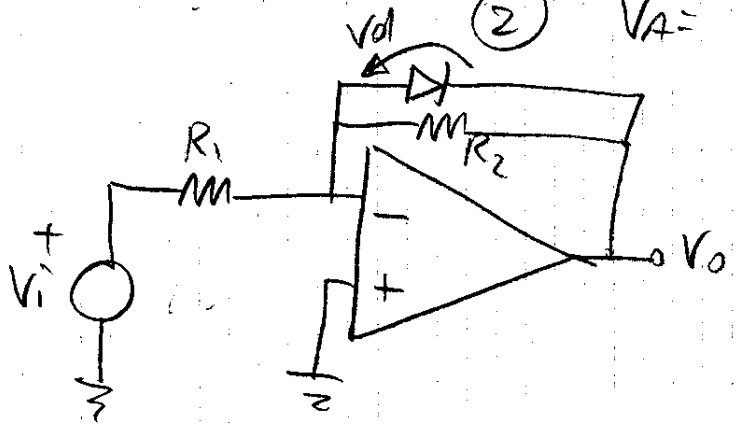


$R_2 = 20 k\Omega$
$R_1 = 10 k\Omega$
$V_\gamma = 0.5\ V$





? Vo(t) ? per ① $V_A = V_i$; $V_B = 0$
② $V_A = 0$; $V_B = V_i$

① 

- Diodo in reazione : reaz. è sempre negativa (sia. + DON che + OFF)

- Senza DIODO :

$$V_o = -\frac{R_2}{R_1} V_i = -2 V_i$$

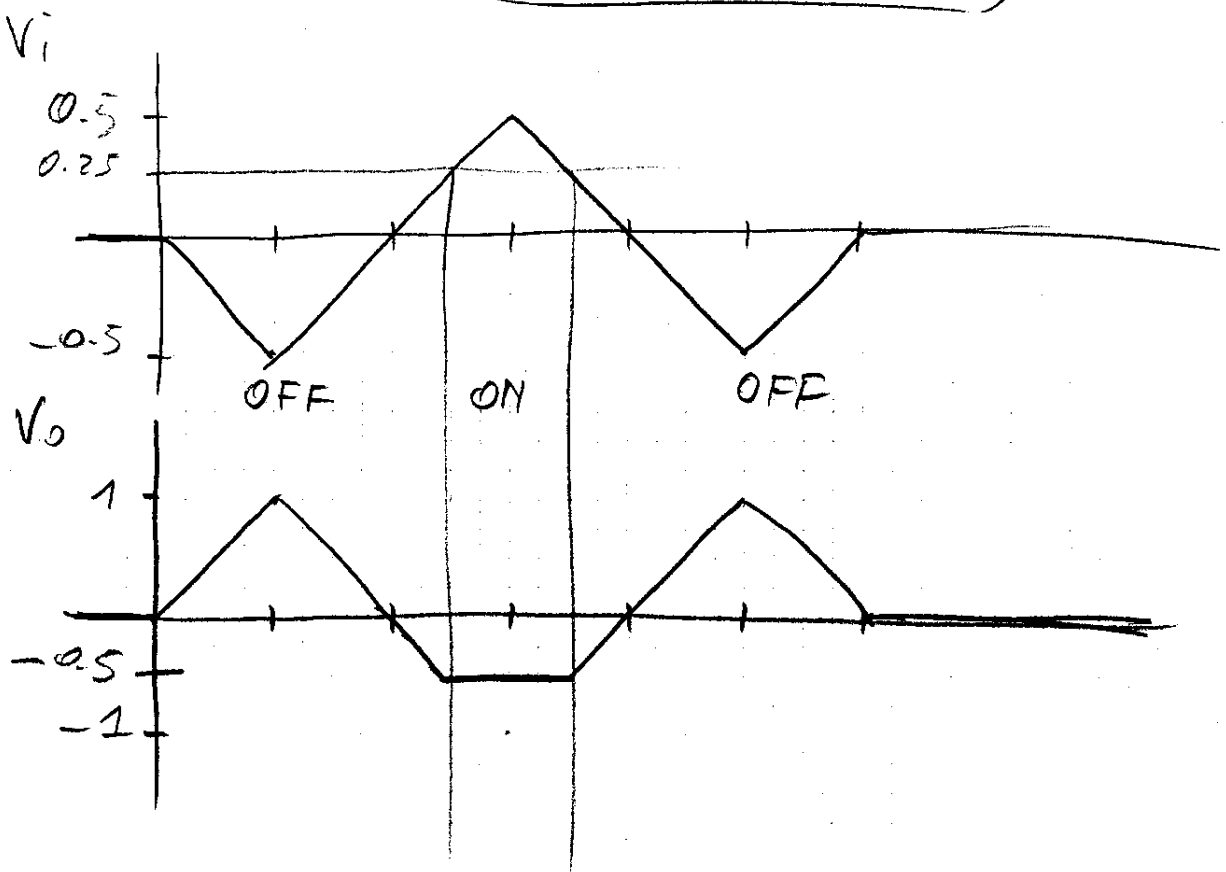
DIODO : OFF se $V_d < V_\gamma = 0.5\ V$

$V_d = V^- - V_o = 0 - V_o = -V_o = +2 V_i$

D OFF: $2v_i < V_\gamma$

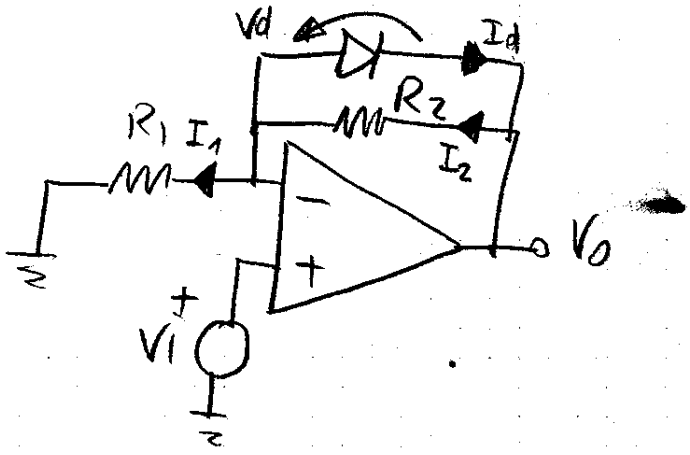
$v_i < \frac{V_\gamma}{2} = +0.25\ V$

(altrim. : D ON)



D ON: $v_o = -V_\gamma = -0.5$

(2)



- Senza DIODO:

$v_o = \left(1 + \frac{R_2}{R_1}\right) v_i = +3 v_i$

$v_d = v^- - v_o = v_i - 3v_i = -2v_i$

D OFF se $v_d < V_\gamma = 0.5\ V$

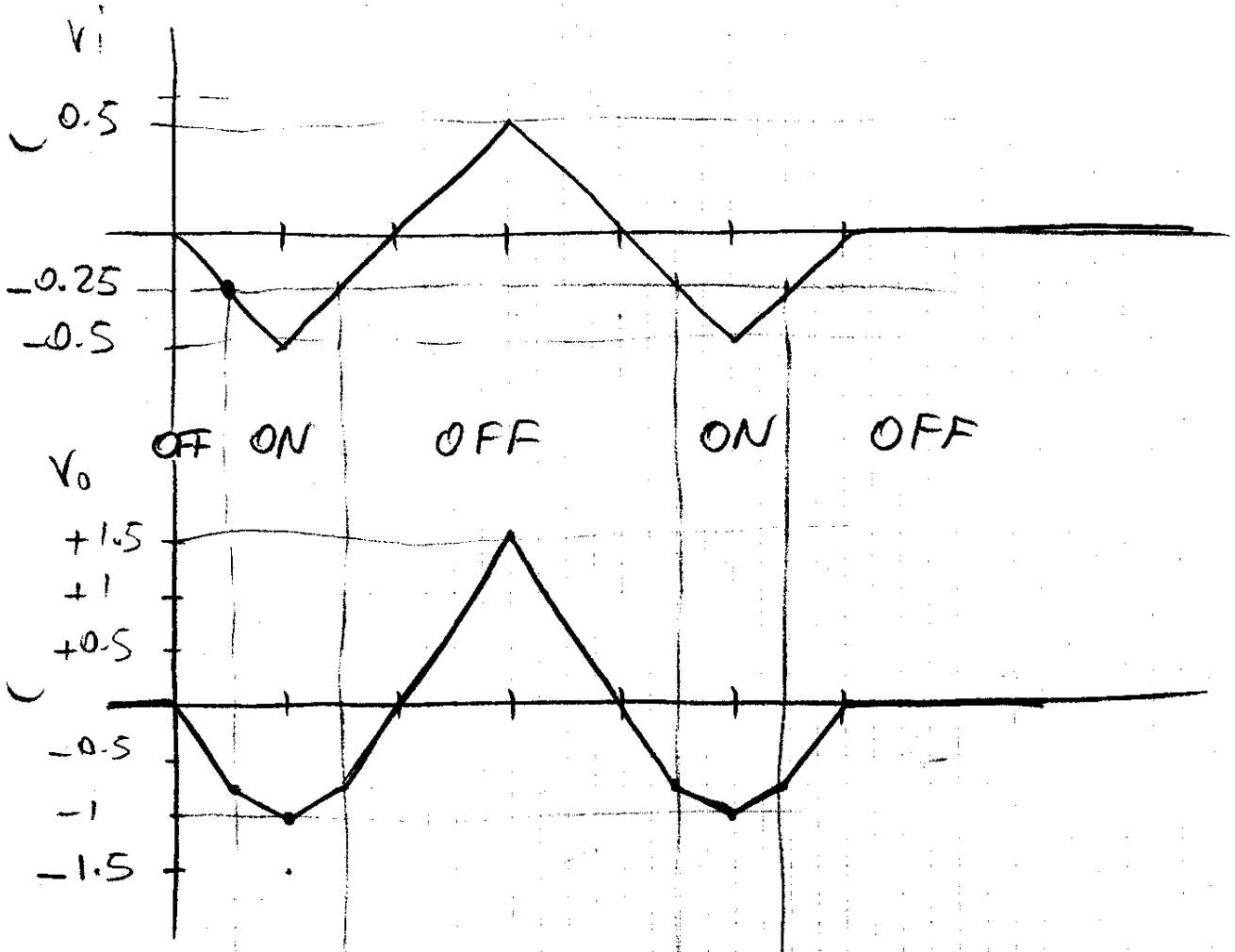
D OFF : $-2v_i < V_\gamma$

$$v_i > -\frac{V_\gamma}{2} = -0.25\ V$$

(altrimenti: D ON)

D OFF : $V_o = +3\,v_i$

D ON : $V_o = V^- - V_d = v_i - V_\gamma = v_i - 0.5$



Verifica D ON : ? $I_d \geq 0$?

$$I_d = I_2 - I_1$$

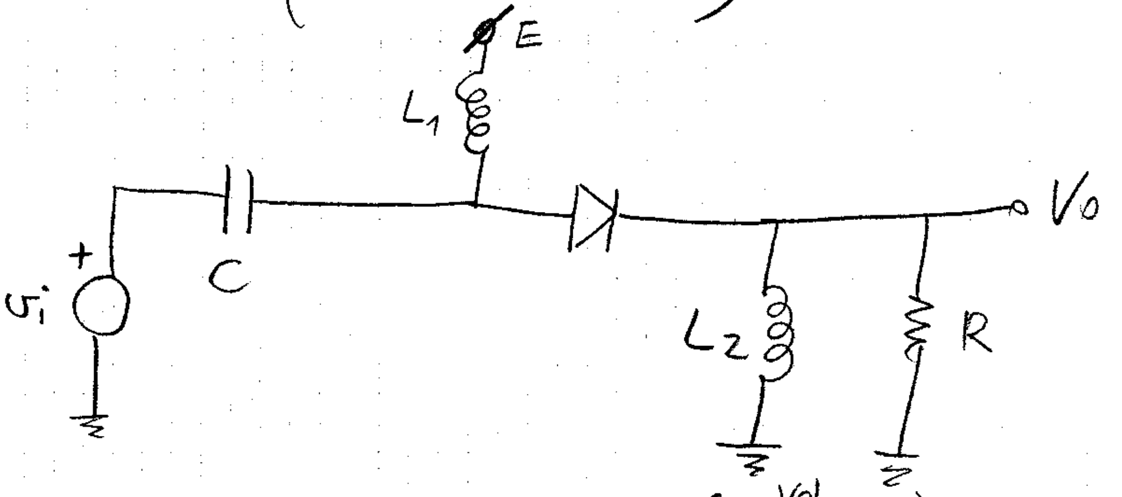
$$I_1 = \frac{V^-}{R_1} = \frac{v_i}{R_1}$$

$$I_2 = -\frac{V_\gamma}{R_2}$$

$$I_d = -\frac{V_\gamma}{R_2} - \frac{v_i}{R_1} \geq 0 \quad \rightarrow \quad v_i \leq -\frac{R_1}{R_2} V_\gamma$$

$$v_i \leq -\frac{V_\gamma}{2} = -0.25\ V$$ OK

• ES - (SC. 17/5/96)



DIODO REALE: $I_d = I_S \left(e^{V_d/V_T} - 1 \right)$; $I_S = 5 \cdot 10^{-15}$ A

$R = 1\ k\Omega$

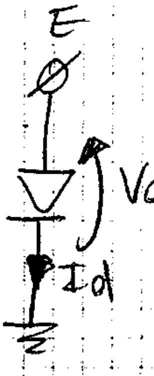
$E = +0.65\ V$

① Punto di lavoro
② r_d del diodo ?
③ $\frac{v_o}{v_i}$ per $\omega \to \infty$
④ Det $F(s) = \frac{v_o}{v_i}$ per $L_1, L_2 \to \infty$, $C = 10\,mF$
Bode
⑤ ? Val. di E per cui $\frac{v_o}{v_i} = 0$ per $\omega \to \infty$

---

① Punto di lavoro: in CONTINUA dell. correnti e tens.

(C → aperto
L → CTO CTO)



Se D fosse ideale: sarebbe ON

Quindi: $I_d \simeq I_S\, e^{V_d/V_T}$

$V_d = E$

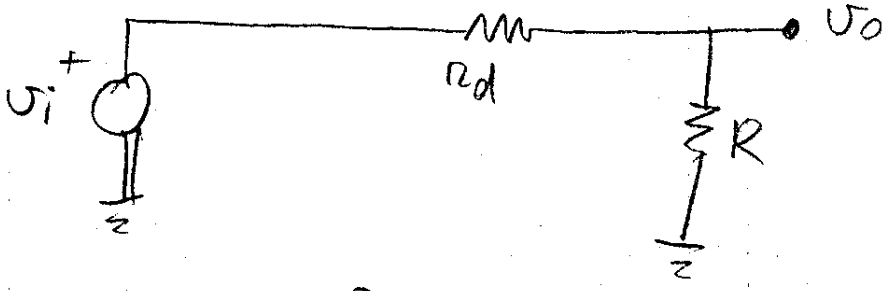
$I_d \simeq I_S\, e^{V_d/V_T} = 5 \cdot 10^{-15} \cdot e^{\frac{0.65}{0.025}} =$

$= 0.98\ mA$

$V_o = 0$

② $r_d \simeq \frac{V_T}{I_d} = \frac{25\,mV}{0.98\,mA} \simeq 25\,\Omega$

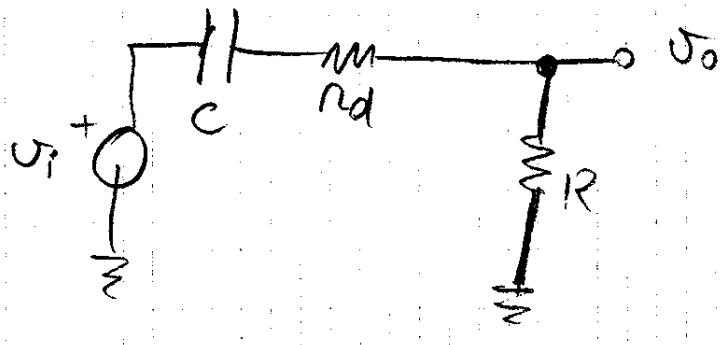
③ $\omega \to \infty$: $C \to$ c.to c.to
$L \to$ circ. ap.



$\frac{v_o}{v_i} = \frac{R}{R+R_d} = \frac{1000}{1025} = 0.975$

④ $z_L = s \cdot L$ $\quad L \to \infty \Rightarrow z_L \to \infty$

$L \to$ circ ap.



$\omega \to 0$ $\quad F(s) = 0$

$\omega \to \infty$ $\quad F(s) = \frac{R}{R+r_d}$

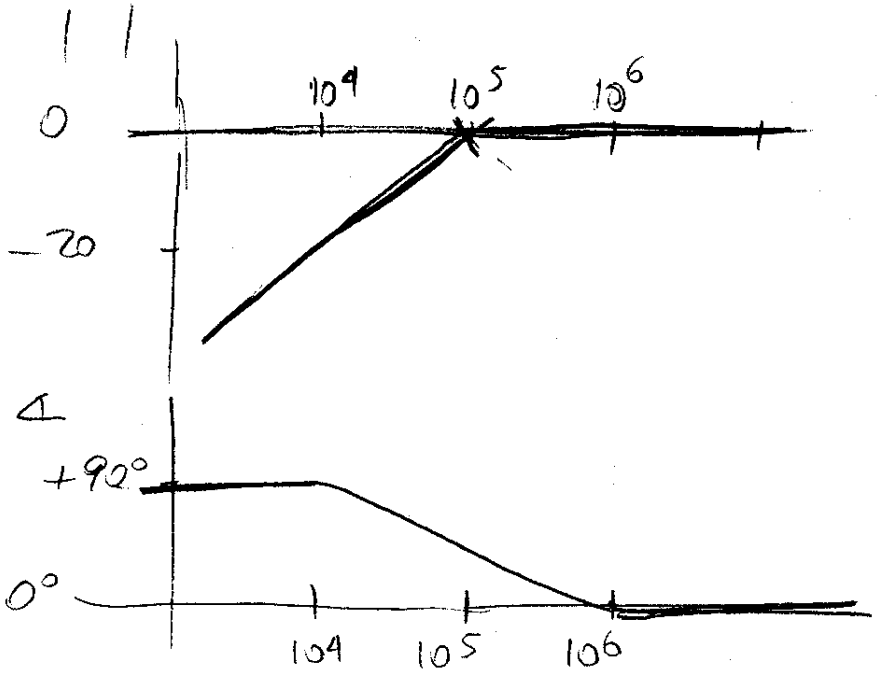
$F(s)$ è F. d. T. passa - alto

$F(s) = K \cdot \frac{s\tau}{1+s\tau}$

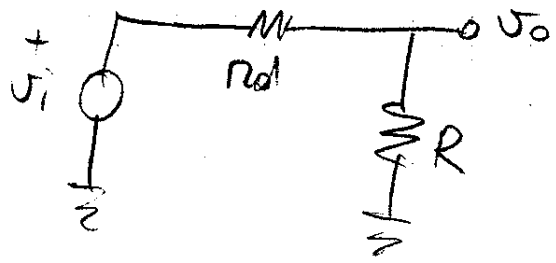
$K = \frac{R}{R+r_d} = 0.975 = -0.2\,dB$

$\tau = C(r_d + R) = 10^{-8} \cdot 1025 \simeq 10^{-5}\,s$

$z_p = -10^5\,r/s$



(5) $\omega \to \infty$



Prendo $E \leq 0$ V

Voglio $\frac{V_o}{V_i} \to 0 \Rightarrow \frac{R}{R + r_d} \to 0 \Rightarrow r_d >> R$

$$r_d = \frac{V_T}{I_S \cdot e^{V_d/V_T}} = \frac{V_T}{I_S \cdot e^{E/V_T}} >> R$$

$$e^{E/V_T} \ll \frac{V_T}{I_S R} \qquad \text{uso} =$$

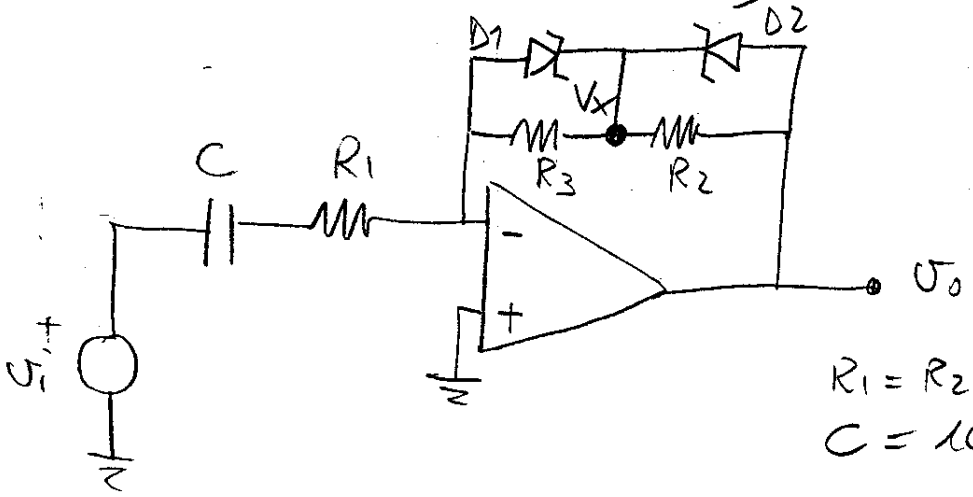
$$E = V_T \ln \frac{V_T}{I_S R} = 25 \cdot 10^{-3} \cdot \ln \frac{25 \cdot 10^{-3}}{5 \cdot 10^{-15} \cdot 10^3} =$$

$$= 25 \cdot 10^{-3} \cdot 22.33 = 0.558 \text{ V}$$

Esempio: prendo $E = 0.5$ V:

$$r_d = \frac{25 \cdot 10^{-3}}{5 \cdot 10^{-15} \cdot e^{\frac{0.5}{0.025}}} = 10 \text{ k}\Omega \qquad \left(\frac{V_o}{V_i} \simeq 0.1\right)$$

• ES. (SCRITTO © 30/11/93)



$V_\gamma = 0.7\ V$

$V_Z = -5.1\ V$

$R_1 = R_2 = R_3 = 10\ k\Omega$

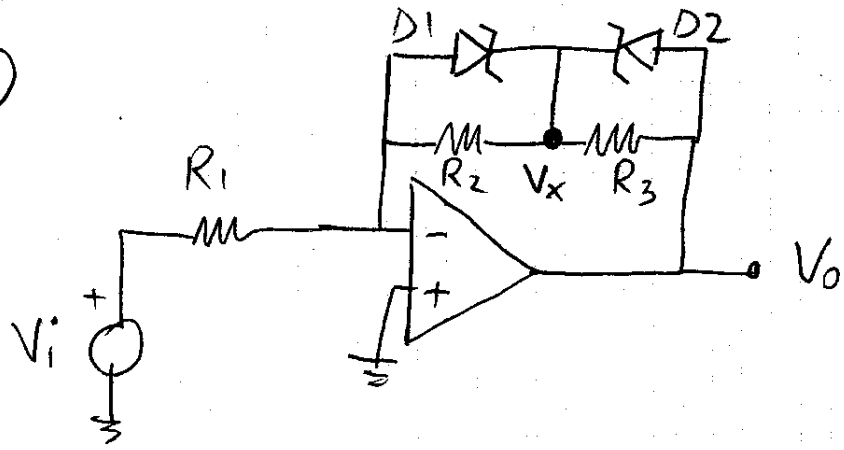
$C = 100\ \mu F$

① C = CTO CTO : $V_o = V_o(V_i)$

② NO DIODI : F.d.T $\frac{V_o}{V_i}$ e Bode

③ SI DIODI, SI C : risposta grad. unit.

①



- NO DIODI : $V_o = -\frac{R_2+R_3}{R_1} \cdot V_i = -2\,V_i$

$$V_x = \frac{V_o}{2} = -V_i$$

- DIODI : $V_{d1} = V^- - V_x = -V_x = V_i$

$V_{d2} = V_o - V_x = -V_i$

! (reaz. sempre chiusa)

→ Diodi: non entrambi in Zener o Pol. Dir non uno OFF e l'altro Zener (prima uno va in POL DIR)

D1 D2

Ⓐ OFF OFF $\Rightarrow$ $V_o = -2V_i$

$V_z < V_i < V_\gamma$ $V_z < V_i < V_\gamma$ $\longrightarrow$ $\begin{cases} V_z < V_i < V_\gamma \\ -V_\gamma < V_i < -V_z \end{cases} \Rightarrow \underline{-V_\gamma < V_i < V_\gamma}$

Ⓑ OFF POL. DIR $\Longrightarrow$ $V_x = -V_i$

$V_z < V_i < V_\gamma$ $V_{d2} = V_\gamma$ $\boxed{V_o = V_x + V_{d2} = -V_i + V_\gamma}$

complementare a caso Ⓐ:

$\underline{V_z < V_i < -V_\gamma}$

Ⓒ ZENER POL. DIR $\Longrightarrow$ $\boxed{V_o = -V_{d1} + V_{d2} = -V_z + V_\gamma = +5.8\ V}$

$V_{d1} = V_z$ $V_{d2} = V_\gamma$

quando si avrebbe (senza diodi):

$V_{d1} < V_z$

$\underline{V_i < V_z = -5.1}$

Ⓓ POL DIR OFF $\Longrightarrow$ $\boxed{V_o = -V_i - V_\gamma}$

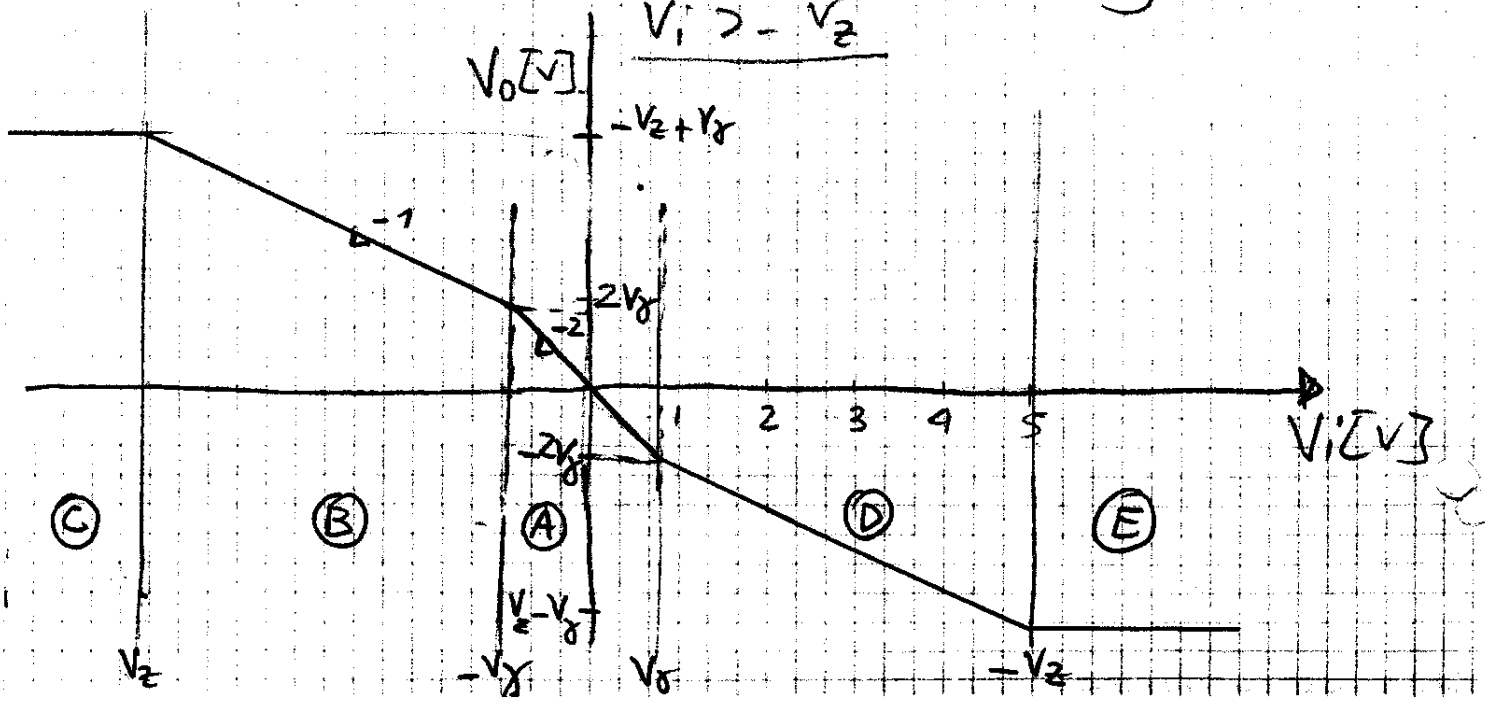
$V_{d1} = V_d$ $V_z < -V_i < V_\gamma$

$\underline{V_\gamma < V_i < -V_z}$

Ⓔ POL DIR ZENER $\Longrightarrow$ $\boxed{V_o = -V_\gamma + V_z}$

SIMMETRICI risp. Ⓑ, Ⓒ

$V_i > -V_z$



(2) $F(s) = \frac{U_o}{U_i} = \frac{-Z_2}{Z_1} = -\frac{R_2 + R_3}{R_1 + \frac{1}{sC}} =$

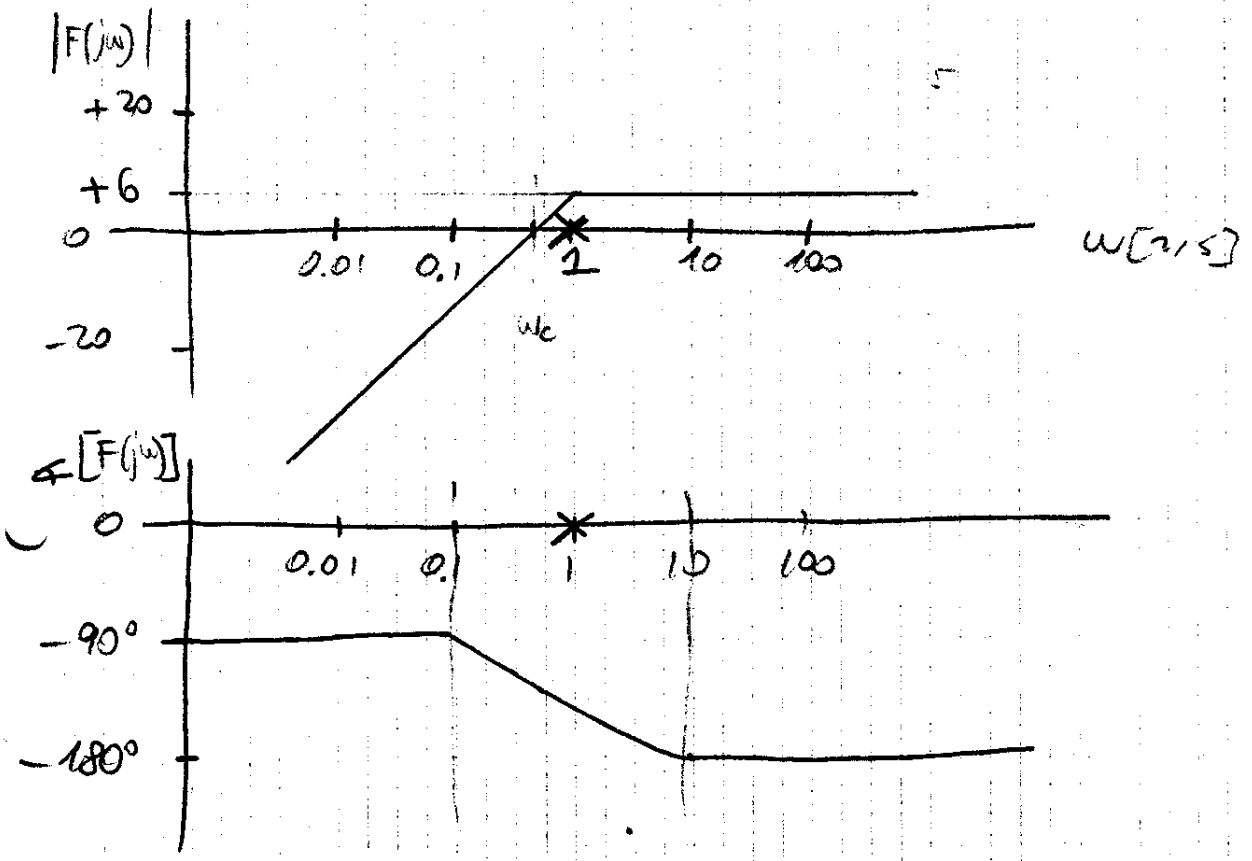
$= -\frac{sC(R_2+R_3)}{1+sCR_1}$

Zero nell'orig.

polo: $-\frac{1}{CR_1} \rightarrow \omega_p = \frac{1}{CR_1} = \frac{1}{10^{-9} \cdot 10^9} = 1$ r/s

solo zero: $\omega_c = \frac{1}{C(R_2+R_3)} = 0.5$ r/s

$\omega \rightarrow \infty$: $|F| \rightarrow 2 = +6$dB



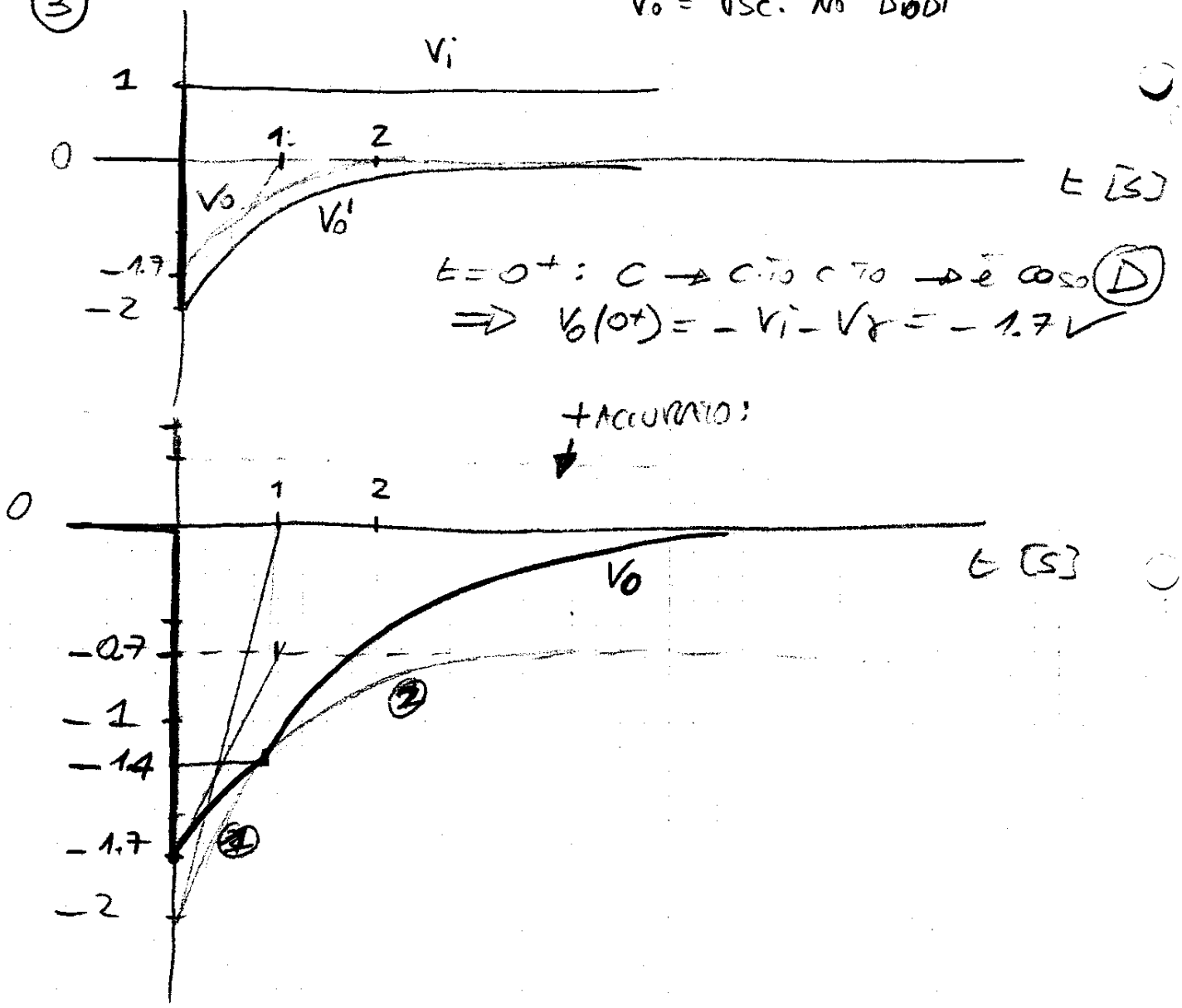
ANCHE: (+ facile):

$F(s) = -\frac{R_2+R_3}{R_1} \cdot \frac{sCR_1}{1+sCR_1} = -2 \cdot \frac{s \cdot 1}{1+s \cdot 1}$

è PASSA ALTO con guad = 2 = 6dB

e $\omega_p = 1$ r/s

(3) V_o' = USC. NO DIODI



$t = 0^+$: C → CTO CTO → è COSÌ (D)

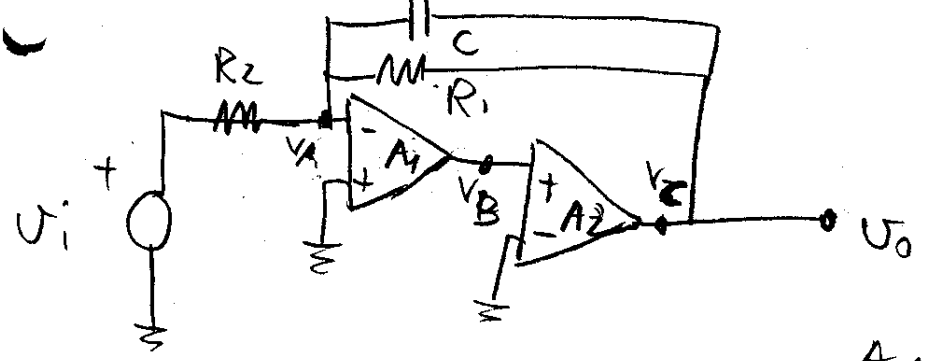
$\Rightarrow V_o(0^+) = -V_i - V_\gamma = -1.7\,V$ ✓

andamento ① Parte da −1,7
Tende a −0.7 ($\Delta V = 1\,V$)

" ② da −2
a 0

INTERSEZ : (D2 ON → OFF) per $V_o = -1.4\,V$

• SC. 21/6/94 (IMPOSTAZIONE)



$R_1 = 1\ K\Omega$
$R_2 = 10\ K\Omega$
$C = 100\ nF$

$A_1 = 10^6$
$A_2 = 10$

AO id (Tranne guad)

① F.d.T $\frac{V_o}{V_i}$ e Bode (Ragionevoli approx!)

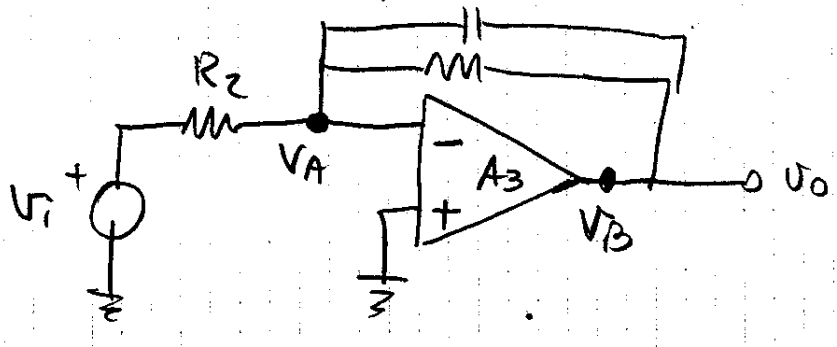
② Risp. gradino

$$V_B = A_1 (V_1^+ - V_1^-) \doteq - A_1 V_A$$

$$V_C = A_2 (V_2^+ - V_2^-) = A_2 V_2^+ = A_2 \cdot V_B =$$

$$= A_2 (- A_1 V_A) = - A_1 \cdot A_2 \cdot V_A$$

Circ. equivalente:

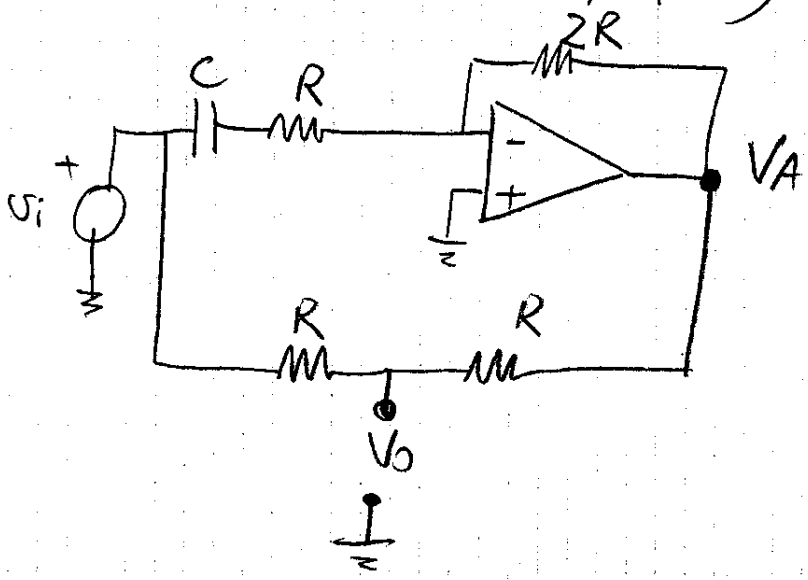


$$A_3 = A_1 \cdot A_2 = 10^6 \cdot 10 = 10^7$$

$$V_A = - \frac{V_o}{A_3} = - \frac{V_o}{10^7} \simeq 0 \quad - - - -$$

Buona appr: V_A = massa virt.

- ES (SC. 27/9/94)



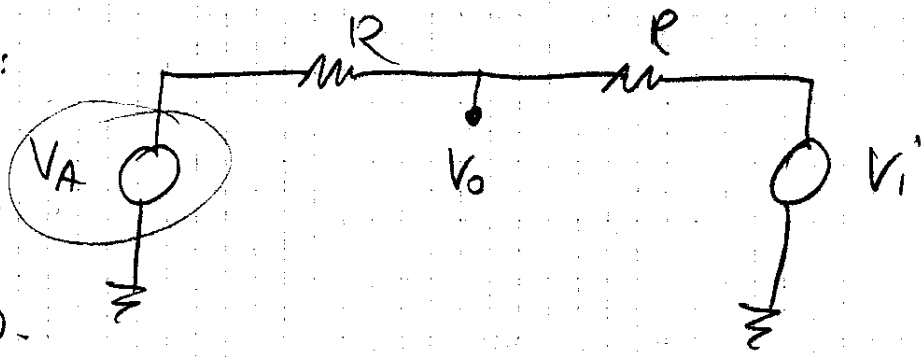
$C = 1\,\mu F$

$R = 10\,k\Omega$

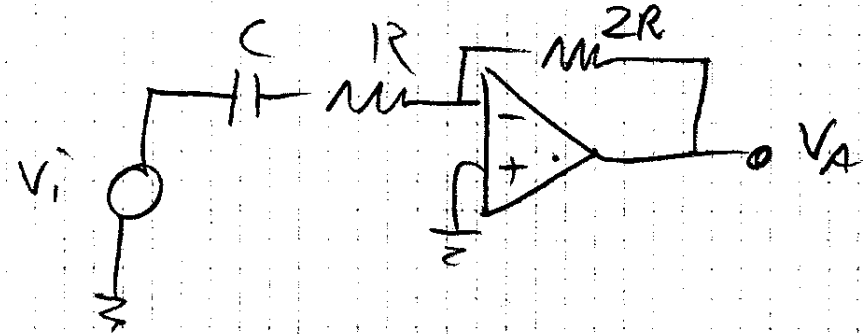
① F.d.T. $\frac{V_o}{V_i}$ e Bode

② ? V_o ? per $v_i(t) = 1 + \sin(1000t)$ [V]

① è come:



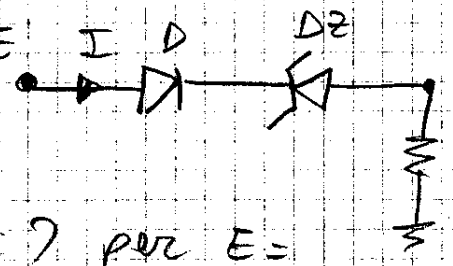
Uscita di A.O.
id. non dip. da ciò che c'è tra uscita (V_A) e massa



CORREZIONE COMPITO IN ITINERE 43
21/11/97

ES. 1

(A)



$V_\gamma = 0.7$ V
$V_Z = -5$ V

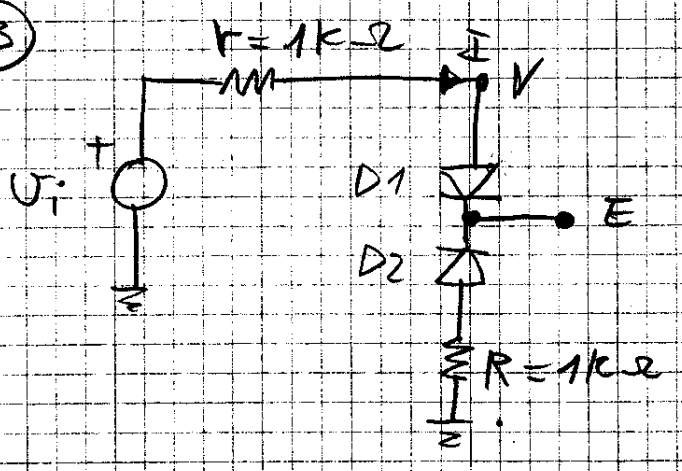
? I ? per E =
+15 V
−15 V
0 V

- $E = 0$ $I = 0$
- $E = +15$ V D ON, DZ ZENER

$$I = \frac{E - V_\gamma + V_Z}{R} = \frac{15 - 0.7 - 5}{10^3} = \frac{9.3}{10^3} = +9.3 \text{ mA}$$

- $E = -15$ V $I = 0$

(B)

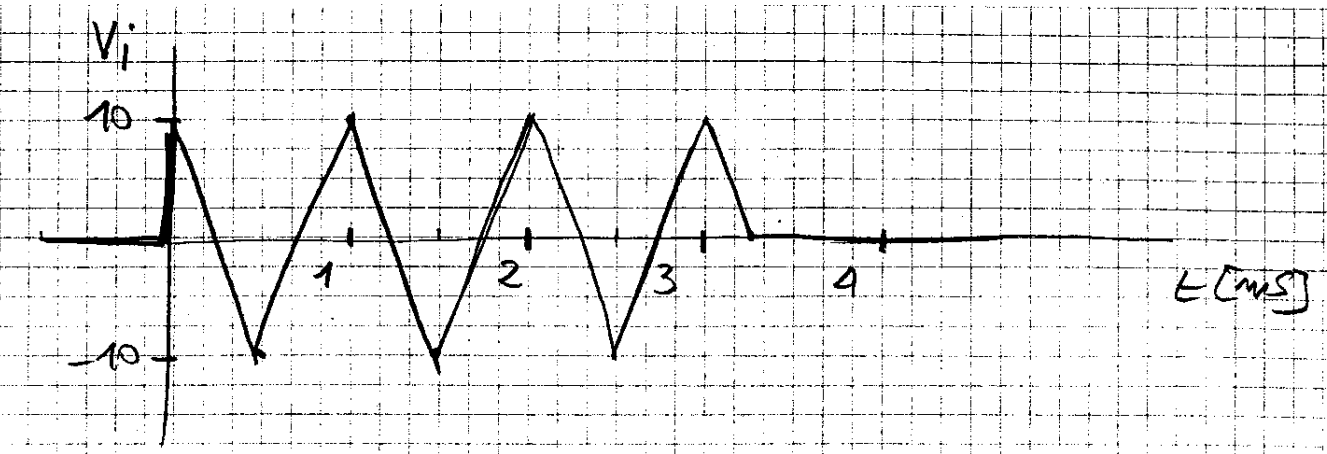


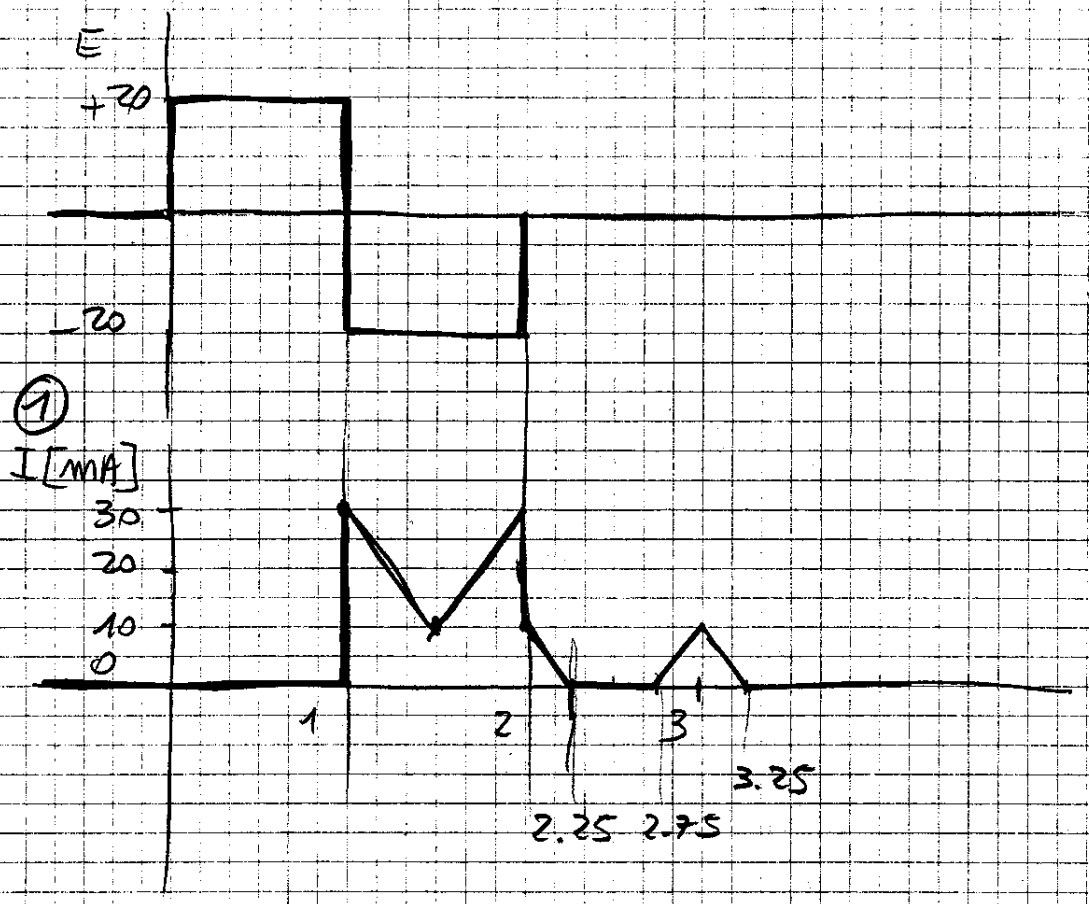
$V_\gamma = 0$ V

$V_i(t)$
$E(t)$ vedi figura

① $I(t)$

② $I(t)$ in assenza di E





① I [mA]

- $t < 0$ $\quad I = 0$

- $0 < t < 1$ $\quad E = +20\ V$ $\quad D2 = OFF$, $D1 = OFF$ $\Big\}$ $I = 0$

- $1 < t < 2$ $\quad E = -20\ V$ $\quad D2$ ON, $D1$ ON

$$I(t) = \frac{V_i(t) - V(t)}{R} = \frac{V_i(t) - E(t)}{R}$$

$$I_{max} = \frac{10 - (-20)}{10^3} = +30\ mA$$

$$I_{min} = \frac{-10 - (-20)}{10^3} = +10\ mA$$

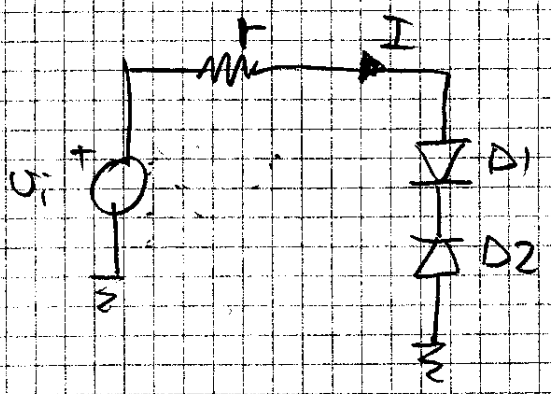
- $t > 2$ $\quad E = 0$ $\quad$ D2 OFF (o ON) $\quad$ 44

D1 < ON se $V_i > 0$; OFF se $V_i < 0$

$I(t)$ < 0 se $V_i < 0$; $\frac{V_i(t) - 0}{r} = \frac{V_i(t)}{r}$ $\quad V_i > 0$

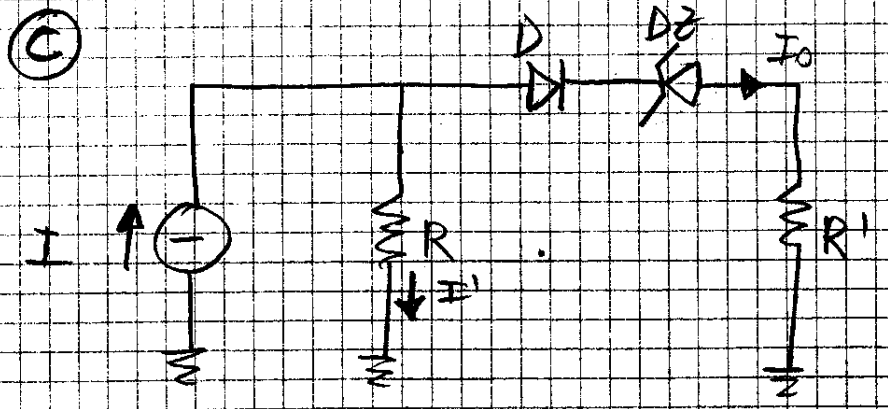
$I_{max} = \frac{10}{10^3} = 10\,mA$

② NO E:



2 diodi in serie – Unica possibilità: D1 OFF, D2 OFF (+ qualunque V_i) $\Rightarrow$ **I = 0**

③



$R = R' = 1\,k\Omega$

$V_1 = 0$ V

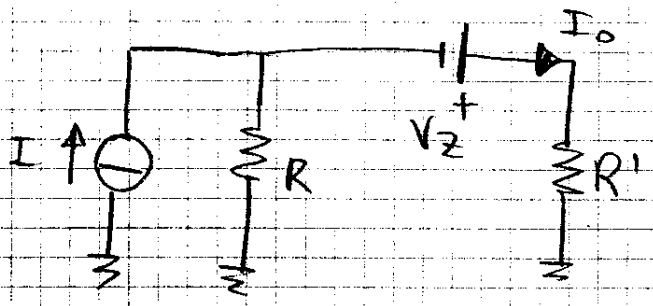
$V_2 = -5$ V

? I_0 ? per $I = \begin{matrix} +10 \\ 0 \\ -10 \end{matrix}$ mA

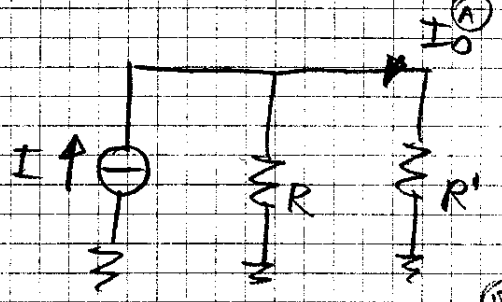
- $I = 0$ D OFF $I_0 = 0$
  DZ OFF

- $I = -10\,mA$ D OFF $I_0 = 0$
  DZ OFF

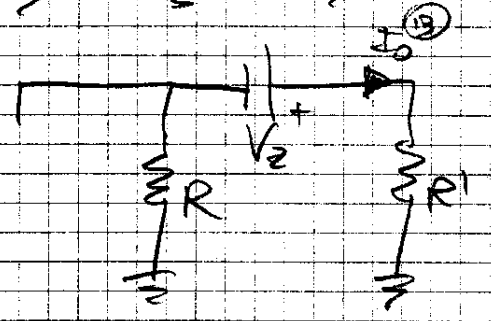
- $I = +10\,mA$ D ON
  DZ ZENER



Uso sovrapposizione degli effetti:



$$I_0^{(A)} = I \cdot \frac{R}{R+R'} = \frac{I}{2} = +5\,mA$$



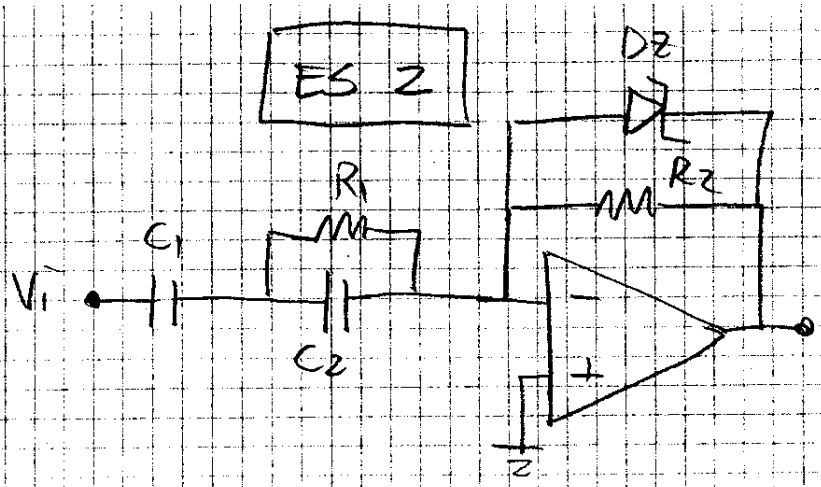
$$I_0^{(B)} = \frac{V_Z}{R+R'} = \frac{-5}{2 \cdot 10^3} =$$

$$= -2.5\,mA$$

$$I_0 = I_0^{(A)} + I_0^{(B)} = +5 - 2.5 = +2.5\,mA$$

Verifica? Immediata ($I_0 > 0$)

ES 2



$R_1 = 1\ k\Omega$
$R_2 = 100\ k\Omega$
$C_1 = 100\ nF$
$C_2 = 10\ \mu F$
$V_\gamma = 0.7\ V$
$V_z = -5\ V$
AO id

① NO Dz: $\frac{V_o}{V_i}$, Bode, qual
② $e_{OFF} = +5\ mV$
③ $v_i(t) = 10^{-2} \sin(10^6 t)\ V$
④ SI Dz: V_i sinus ampl. 100 mV
$f = 160\ kHz$

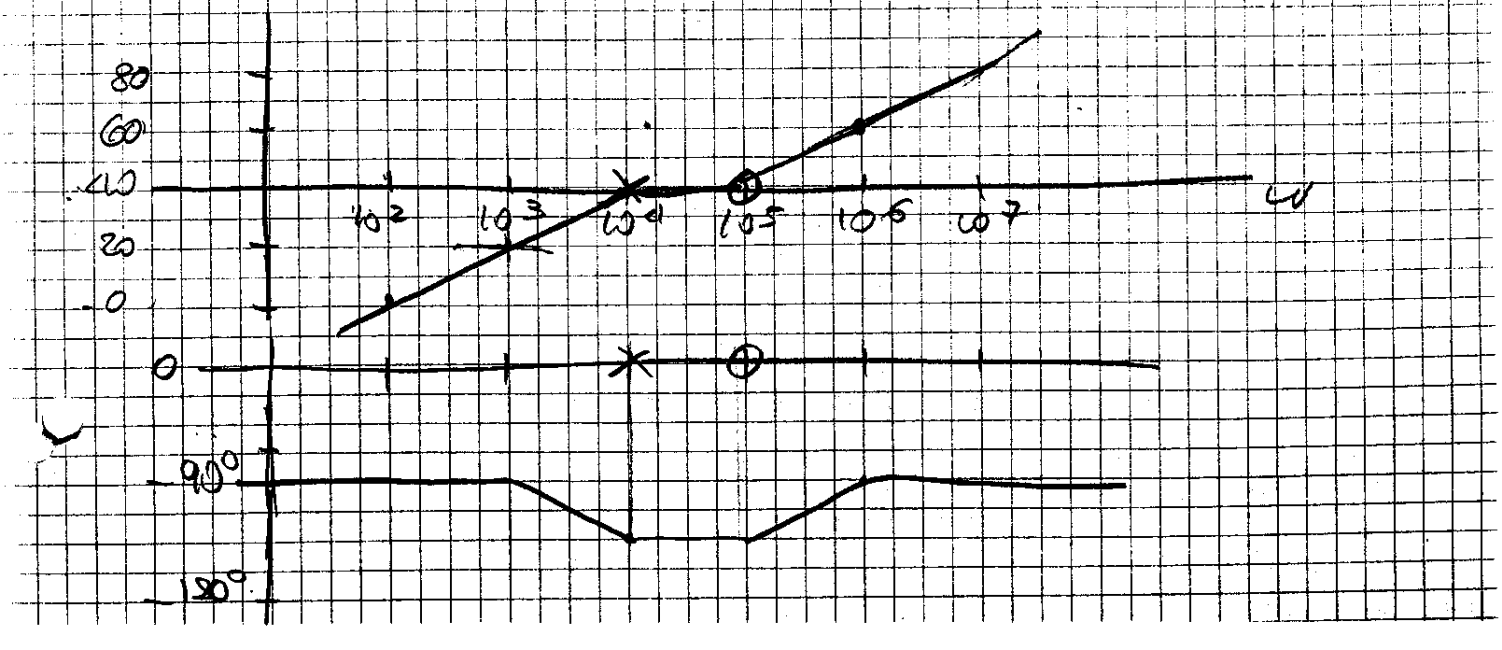
① $\frac{V_o}{V_i} = -\frac{R_2}{Z}$

$$Z = \frac{1}{sC_1} + \frac{R_1/sC_2}{R_1 + \frac{1}{sC_2}} = \frac{1+sR_1(C_1+C_2)}{sC_1(1+sR_1C_2)}$$

$$\frac{V_o}{V_i} = -\frac{R_2}{Z} = -\frac{sC_1R_2(1+sR_1C_2)}{1+sR_1(C_1+C_2)}$$

$$T(s) = -5\cdot 10^{-2}\,\frac{1+5\cdot 10^{-5}}{1+5\cdot 1.1\cdot 10^{-9}}$$

$\omega_c = 10^2\ rad/s$



Risposta al gradino: Teor. val. iniz. e fin.:

$$\lim_{t\to 0^+} v_0(t) = -\infty \;, \quad \lim_{t\to +\infty} v_0(t) = 0$$

$$T(s) = -s\tau_1 \frac{(1+s\tau_2)}{1+s\tau_3} = -s\tau_1 \left[\frac{1}{1+s\tau_3} + \frac{s\tau_2}{1+s\tau_3}\right]$$

$$= -s\tau_1 \left[\frac{1}{1+s\tau_3} + \frac{\tau_2}{\tau_3}\cdot\frac{s\tau_3}{1+s\tau_3}\right]$$

$\tau_1 = 10^{-2}\,s$
$\tau_2 = 10^{-5}\,s$
$\tau_3 \simeq 10^{-9}\,s$

$$v_0(t) = -\tau_1 \cdot \frac{d}{dt}\left[v_{0,PB}(t) + \frac{\tau_2}{\tau_3} v_{0,PA}(t)\right]$$

$$v_{0,PB}(t) = \left(1 - e^{-t/\tau_3}\right)\cdot sca(t)$$

$$v_{0,PA}(t) = \frac{\tau_2}{\tau_3}\cdot e^{-t/\tau_3}\cdot sca(t) \simeq 0.1\, e^{-t/\tau_3}\cdot sca(t)$$

$$v_0(t) = -\tau_1^2 \cdot \frac{d}{dt}\left\{\left[1 - e^{-t/\tau_3} + 0.1\, e^{-t/\tau_3}\right]\cdot sca(t)\right\}$$

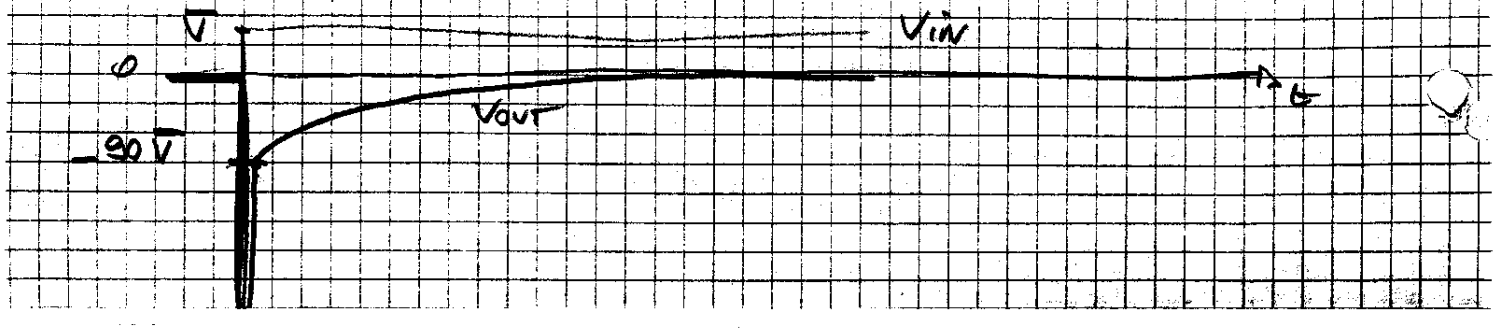
$$= -\tau_1 \frac{d}{dt}\left\{\left[1 - 0.9\, e^{-t/\tau_3}\right]\cdot sca(t)\right\} =$$

$$= -\tau_1 \left[\delta(t) + \frac{0.9}{\tau_3} e^{-t/\tau_3}\cdot sca(t)\right] =$$

$\delta(t)\cdot p(t) = \delta(t)\cdot p(0)$

$$= -k\,\delta(t) - 0.9\,\frac{\tau_1}{\tau_3}\cdot e^{-t/\tau_3}\, sca(t) =$$

$$= -k\,\delta(t) - 90\, e^{-t/\tau_3}\cdot sca(t).$$



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(2) $e_{OFF} = +5 \text{ mV}$, $V_0 = + e_{OFF} = +5 \text{ mV}$

(3) $\omega_S = 10^6 \text{ r/s}$

$V_{IN}(t) = 10^{-2} \sin(10^6 t)$

$V_{OUT}(t) = 10 \sin\left(10^6 t - \frac{\pi}{2}\right)$

(4) $f_S = 160 \text{ KHz}$

$\omega_S = 2\pi f_S \cong 10^6 \text{ r/s}$

$|F(j\omega)| = +60 \text{ dB} = 1000$

$V_{OUT} = 100 \text{ V}$ ✓