T.E. circuiti e misure elettroniche

F) verificare calibraz. oscilloscopio (con e senza sonda 10x) mediante il calibratore ut: set up e scale?

?

G) Collegam. e scale per V_B?

$V_{PP} = 622V$ $\frac{622V}{8 div} = 77{,}75V$ → $A_y = 100V/div$ uguale troppo ampio per essere rilevato correttam. dall'oscillosc. ($A_{y\,max} = 5V/div$)
⊕ sonda 10x [...] → $A_y = 10V/div$ non basta
⊕ sonda 100x → $A_y = 1V/div$
$f = 50Hz$ → $T = 0{,}02\,s$ $\frac{0{,}02s}{10 div} = 2ms/div$ → $A_x = 2ms/div$

H) impostaz. osc. x misura solo V_A? [...]

I) calibratore: Tempo di salita = 6ns → Tempo di salita osservato con oscilloscopio x epu. di calibrazione

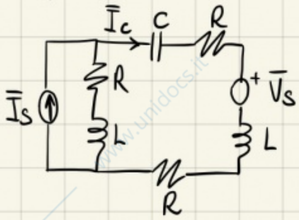
f

J) $u(V_A) = ?$ $u_r(V_A) = ?$ oscilloscopio

$u(V_A) = \frac{A_y \cdot 8}{N} \cdot \frac{1}{\sqrt{12}} = \frac{A_y \cdot 8}{2^n} \cdot \frac{1}{\sqrt{12}} = 1{,}8mV$ $u_r(V_A) = \frac{u(V_A)}{V_A}$

K) $u(V_A) = ?$ $u_r(V_A) = ?$ voltmetro

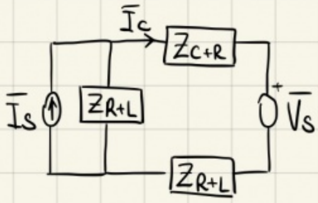
ES 2



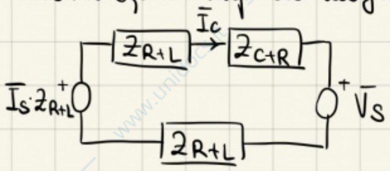
$\omega = 1\,\text{krad/s}$
$i_s(t) = 1\cos(\omega t)\ A$
$v_s(t) = 1 \sin(\omega t)\ V = 1\cos(\omega t - \pi/2)\ V$
$L = 1\,mH$
$C = 200\,\mu F$
$R = 1\,\Omega$

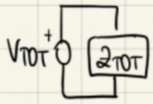
A) impedenze: singole e in serie?

$Z_R = R \quad , Z_L = j\omega L \ , Z_c = 1/j\omega C$
$Z_{R+L} = R + j\omega L = (1+j)\,\Omega$
$Z_{C+R} = R - \dfrac{j}{\omega C} = (1 - j/0{,}2)\,\Omega = (1-5j)\,\Omega$



B) circuito eq. con singola maglia?





$\bar{I}_s = 1e^{j\cdot 0} A = 1A$
$\bar{V}_s = 1e^{-j\pi/2} V = -j\,V$
$\bar{V}_{TOT} = \bar{I}_s Z_{R+L} - \bar{V}_s = (1+j)V + jV = (1+2j)V$
$Z_{TOT} = 2Z_{R+L} + Z_{R+C} = 2(1+j)R + (1-5j)R = (3-3j)R$

C) $I_c = ?$ $\quad \bar{I}_c = \dfrac{V_{TOT}}{Z_{TOT}} = \dfrac{(1+2j)V}{(3-3j)R} = (-0{,}167 + 0{,}5j)\,A$

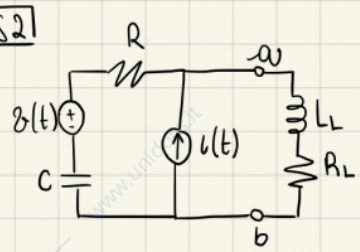
D) $i_c(t) = ?$

$|\bar{I}_c| = \sqrt{0{,}167^2 + 0{,}5^2} = 0{,}527$
$\angle \bar{I}_c = \text{arctg}(0{,}5/-0{,}167) + \pi = 1{,}893\,\text{rad} = 108{,}4^\circ \; \Big] \rightarrow i_c(t) = 0{,}527\cos(1\,\text{krad/s}\ t + 108{,}4^\circ)\ A$

E) $E_{C\,MAX}$?

$\bar{V}_c = \bar{I}_c Z_c = (2{,}5 + 0{,}833j)\,V = 2{,}635\,e^{j18{,}4^\circ}\,V \quad \rightarrow v_{c\,max} = 2{,}635V$
$E_{c\,max} = \frac{1}{2} C v_{c\,max}^2 = 0{,}694\,mJ$

ES2



$e(t) = 300\cos(\omega t)\,V$ $\quad L_L = 2H$
$i(t) = 2\sin(\omega t)\,A$ $\quad R_L = 2\Omega$
$C = 33\,\mu F$ $\quad f = 50Hz$
$R = 50\,\Omega$

A) ridisegnare nel dominio dei fasori? Circ eq di Norton per circ ab: $\bar{I}_N, Z_N$?

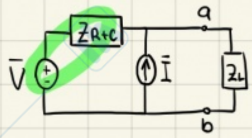
$\omega = 2\pi f = 314{,}164\,rad/s$

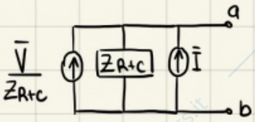
$Z_R = R = 50\,\Omega$, $Z_C = 1/j\omega C = -j/\omega C = -j96{,}4575\,\Omega \Rightarrow Z_{R+C} = (50 - j96{,}4575)\,\Omega$

$\bar{V} = 300\,V$

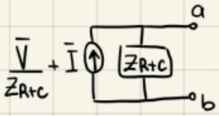
$\bar{I} = 2e^{-j\pi/2} = -2j\,A$

$Z_{L_L} = j\omega L = j628{,}32\,\Omega$, $Z_{R_L} = 2\Omega \Rightarrow Z_L = (2 + j628{,}32)\,\Omega$





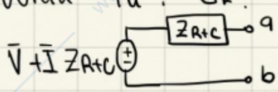
$=$



$\Rightarrow \bar{I}_N = \frac{\bar{V}}{Z_{R+C}} + \bar{I} = \frac{300V}{(50 - j96{,}4575)\,\Omega} - j2A = (1{,}2707 + j2{,}4515)A - j2A = (1{,}2707 + j0{,}4515)A$

$Z_N = Z_{R+C} = (50 - j96{,}4575)\,\Omega$

B) Norton → Th ? $\bar{S}_L$?



$\Rightarrow \bar{V}_T = \bar{I}_N Z_{R+C} = \bar{V} + \bar{I}\,Z_{R+C} = (107{,}08 - j100)\,V$

$Z_T = Z_N = Z_{R+C} = (50 - j96{,}4575)\,\Omega$

partitore di tens: $\bar{V}_L = \frac{Z_L}{\bar{V}_T} = \frac{(2 + j628{,}32)\,\Omega}{(50 - j96{,}4575)\,\Omega + (2 + j628{,}32)\,\Omega} \cdot (107{,}08 - j100)V = (136{,}409 - j105{,}202)V$

$\bar{I}_L = \frac{\bar{V}_L}{Z_L} = \frac{(136{,}409 - j105{,}202)V}{(2 + j628{,}32)\,\Omega} = (-0{,}1667 - j0{,}2176)\,A$

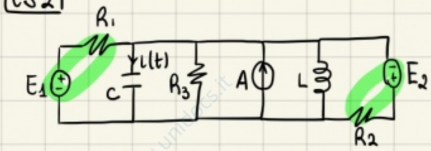
$\bar{S}_L = \frac{1}{2}\bar{V}_L \bar{I}_L^* = \frac{1}{2}(136{,}409 - j105{,}202)V \cdot (-0{,}1667 + j0{,}2176)\,A = (0{,}076 + j23{,}61)\,W$

C) Impedenza di adattamento Z_A da aggiungere a Z_L | massimo trasf di potenza ?

$Z_L + Z_A = Z_{R+C}^*$ $\quad (2 + j628{,}32)\,\Omega + Z_A = (50 + j96{,}4575)\,\Omega \Rightarrow Z_A = (48 - j531{,}8625)\,\Omega$

ES3 [...]

ES 2



$\omega = 1\,krad/s$ $R_1 = 4\,\Omega$

$E_1 = 8\sin(\omega t)\,V$ $R_2 = 2\,\Omega$

$E_2 = 12\cos(\omega t)\,V$ $R_3 = 4\,\Omega$

$A = 4\cos(\omega t)$ $C = 500\,\mu F$

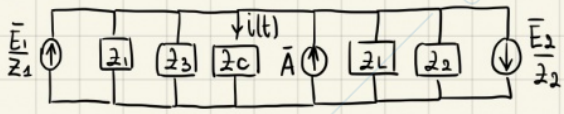
$L = 1\,mH$

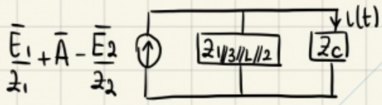
A) $\bar{I} = ?$

$E_1 = 8e^{-j\pi/2}\,V = -j8\,V$ $Z_c = -j/\omega C = -j2\,\Omega$

$E_2 = 12\,V$ $Z_L = j\omega L = j1\,\Omega$

$A = 4\,A$





$\bar{A}_{tot} = \frac{\bar{E}_1}{Z_1} + \bar{A} - \frac{\bar{E}_2}{Z_2} = \frac{-j8V}{4\Omega} + 4A - \frac{12V}{2\Omega} = (-j2+4-6)A = (1-j2)A$

$Z_{TOT} = Z_{1//3//L//2} = [(Z_1 // Z_3) // Z_4] // Z_L = \frac{(1\cdot j1)\,\Omega^2}{(1+j1)\,\Omega} = \frac{j\,\Omega}{1+j} = 0{,}5+j0{,}5$

partitore di corr: $\bar{I} = \frac{Z_{TOT}}{Z_{TOT}+Z_c}\bar{A}_{tot} = \frac{(0{,}5+j0{,}5)\,\Omega}{(0{,}5+j0{,}5-j2)\,\Omega}(1-j2)A = (0{,}6+j0{,}8)A = e^{j0{,}9273}\,A$

B) $i(t) = ?$ in forma analitica e numerica $i(t) = |\bar{I}|\cos(\omega t + \angle\bar{I}) = 1\cos(1000t + 0{,}9273)\,A$

C) $\bar{S}_c = ?$ $P_c = ?$ $Q_c = ?$ $p(t) = ?$

$\bar{V}_c = \bar{I}\cdot Z_c = (0{,}6+j0{,}8)\,A\cdot(-j2)\,\Omega = (1{,}6-j1{,}2)\,V = 2e^{-j0{,}6435}$ $\Rightarrow v_c(t) = 2\cos(1000t - 0{,}6435)$

$\bar{S}_c = \frac{1}{2}\bar{V}_c\bar{I}^* = \frac{1}{2}(1{,}6-j1{,}2)(0{,}6-j0{,}8)\,W = -j1\,W$

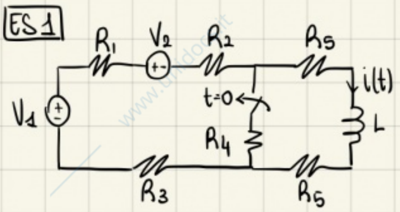
$P_c = Re\{\bar{S}_c\} = 0\,W$

$Q_c = Im\{\bar{S}_c\} = -1\,W$

$p(t) = \frac{1}{2}|\bar{V}_c||\bar{I}|\cos(\theta_v - \theta_i) + \frac{1}{2}|\bar{V}_c||\bar{I}|\cos(2\omega t + \theta_v + \theta_i)$

21/06/21

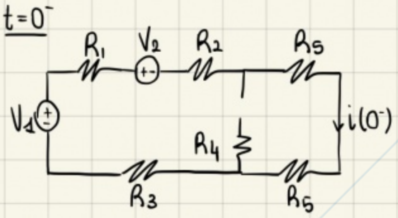
ES 1



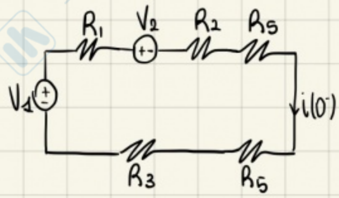
$V_1 = 25V$ $\quad R_3 = 3\Omega$
$V_2 = 5V$ $\quad R_4 = 10\Omega$
$R_1 = 2\Omega$ $\quad R_5 = 5\Omega$
$R_2 = 5\Omega$ $\quad L = 90\,mH$

A) $i(0^+) = ?$ $\;i(\infty) = ?$

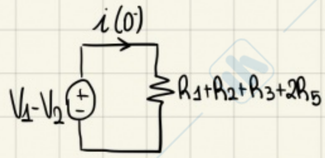
$t = 0^-$



=



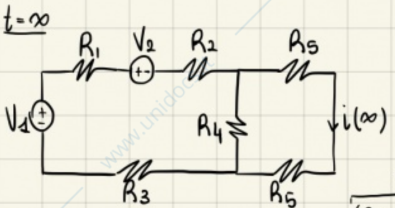
=



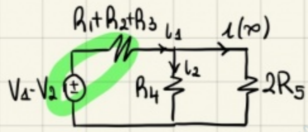
$$i(0^-) = \frac{V_1 - V_2}{R_1+R_2+R_3+2R_5} = \frac{20V}{20\Omega} = 1A$$

$i(0^+) = i(0^-) = 1A$ ← costante di stato

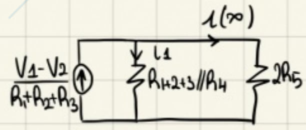
$t = \infty$



=

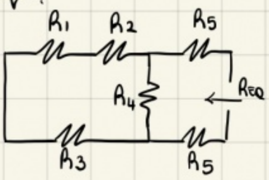


=

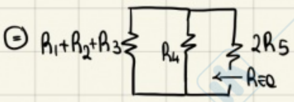


partitore di corrente: $$i(\infty) = \frac{\overbrace{(R_1+R_2+R_3)//R_4}^{5\Omega}}{[(R_1+R_2+R_3)//R_4]+2R_5} \cdot \frac{V_1-V_2}{R_1+R_2+R_3} = \frac{2}{3}A \simeq 0{,}667A$$

B) $\tau = ?$



=



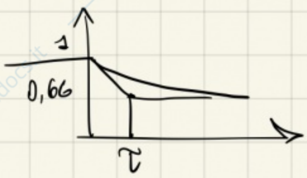
$$R_{EQ} = \underbrace{[(R_1+R_2+R_3)//R_4]}_{5\Omega} + \underbrace{2R_5}_{10\Omega} = 15\Omega$$

$$\tau = L/R_{EQ} = 90mH / 15\Omega = 6ms$$

C) $i(t) = ?$

$$i(t) = [i(0^+) - i(\infty)]e^{-t/\tau} + i(\infty) = [1A - 0{,}667A]\,e^{-t/6ms} + 0{,}667A = 0{,}333A\,e^{-t/6ms} + 0{,}667A$$

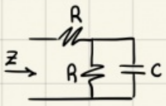
D) grafico $i(t) = ?$



E) $E_L(t=0^+) = ?$ $\quad E_L(t=3\tau) = ?$ $\quad E_L(t=10\tau) = ?$

$$E_L(t=0^+) = \frac{1}{2}L\,i^2(0^+) = 45mJ$$
$$E_L(t=3\tau) = \frac{1}{2}L\,i^2(t=3\tau) = \frac{1}{2}90mH[0{,}333A\,e^{-3} + 0{,}667A]^2 = 21{,}03\ mJ$$
$$E_L(t=10\tau) \simeq E_L(t=\infty) = \frac{1}{2}L\,i^2(\infty) = 20{,}2\ mJ$$

$\boxed{ES2}$



A) $Z=?$ $Im(Z)=?$ $Re(Z)=?$

$Z_R = R$ $\quad Z_C = 1/jWC$ $\quad Z = Z_{R//C} + Z_R = \frac{R/jWC}{R+1/jWC} + R = \frac{R}{jWCR+1}\frac{(jWCR-1)}{(jWCR-1)} + R = \frac{R - jWCR^2}{W^2C^2R^2+1} + R = \frac{R - jWCR^2 + R + W^2C^2R^3}{W^2C^2R^2+1} = \frac{2R + W^2C^2R^3 - jWCR^2}{W^2C^2R^2+1} \Rightarrow$

$$\begin{cases} Re(Z) = \frac{2R+W^2C^2R^3}{W^2C^2R^2+1} = R\frac{2+(WCR)^2}{1+(WCR)^2} \\ Im(Z) = \frac{-WCR^2}{W^2C^2R^2+1} = R\frac{-(WCR)}{1+(WCR)^2} \end{cases}$$

B) $W = 1\,Krad/s$ $\quad X(W)=?$ $\quad X(W) = Im(Z) = R\frac{-(WCR)}{1+(WCR)^2} = -500\,\Omega$

$R = 1\,K\Omega$

$C = 1\,\mu F$

C) generatore Tens $f = 50\,Hz$ $V_{eff} = 220V$ $\quad W = 2\pi f \cong 314\,rad/s$

$Z_G = ?$ massimo trasf di potenza $\quad Z_G = Z_L^* = Z^* = R\frac{2+(WCR)^2}{1+(WCR)^2} + R\frac{(WCR)}{1+(WCR)^2} = (1910 + 286j)\,\Omega$

$\boxed{ES3}$

A) $n = 10$ misure

$C_n = \{1{,}03;\ 1{,}04;\ 0{,}94;\ 0{,}91;\ 1{,}11;\ 0{,}89;\ 1{,}12;\ 0{,}97;\ 1{,}03;\ 0{,}96\}\ pF$

miglior stima? incertezza relativa?

$\bar{C} = \frac{1}{n}\Sigma C_i = 1\,pF$ $\qquad u(C) = \sqrt{\frac{1}{n(n-1)}\Sigma(C_i - \bar{C})} = 25\,fF$ $\qquad u_r(C) = \frac{u(C)}{\bar{C}} = 0{,}025 = 2{,}5\%$

B) $C = \varepsilon_0 \varepsilon_r \frac{S}{d}$

$\begin{cases} S = 1\,mm^2 \quad U_r(S) = 10\% \text{ conf al } 95\% \quad \Rightarrow K=2 \quad \Rightarrow u_r(S) = 5\% = 0{,}05 \\ d = 45\,\mu m \quad u(d) = 1\,\mu m \quad \Rightarrow u_r(d) = 0{,}02 \\ \varepsilon_0 = 8{,}8542 \cdot 10^{-12}\,F/m \quad u(\varepsilon_0) \simeq 0 \end{cases}$

$\varepsilon_r = ?$ $\quad u(\varepsilon_r) = ?$

$\bar{\varepsilon}_r = \frac{\bar{C}}{\varepsilon_0}\frac{d}{S} \cong 5{,}082$ $\qquad u_r(\varepsilon_r) = \sqrt{u_r^2(C) + u_r^2(S) + u_r^2(d) + \cancel{u_r^2(\varepsilon_0)}} = \sqrt{0{,}025^2 + 0{,}05^2 + 0{,}02^2} = 0{,}056 = 5{,}6\%$ $\qquad u(\varepsilon_r) = u_r(\varepsilon_r)\varepsilon_r = 0{,}28$

C) $\varepsilon_r' = 4{,}40\,(40)$ $\Rightarrow \varepsilon_r' = 4{,}40$ $\quad u(\varepsilon_r') = 0{,}40$ $\qquad [\dots]$ $K > 1{,}39 \Rightarrow K = 2$

compatibilita`?

D) Miglior stima e incertezza?

$\boxed{ES3}$

circuito V+R e 3 misure V

ⓐ n=6 misure $V_{Ai}=(8{,}6\ ;\ 8{,}8\ ;\ 8{,}5\ ;\ 8{,}4\ ;\ 8{,}1\ ;\ 8{,}3)\,V$

ⓑ V_B dal $V=RI$ con $R=100\,\Omega\pm3\,\Omega$

$I=85\,mA$ $\quad u_r(I)=8\%$ $\quad K=2$

ⓒ V_C con voltmetro dig.

A) V_A? $u(V_A)$ in notaz. concisa con 2 cifre

$\bar{V}_A=8{,}45V \qquad u(V_A)=\sqrt{\frac{1}{6\cdot5}\Sigma(V_{Ai}-\bar{V}_A)^2}=0{,}0992V\cong0{,}10V \quad \Rightarrow V_A=8{,}45(10)V$

B) $u(u(V_A))=?$

$\nu_{V_A}=n-1=5$

$u_r(u(V_A))\simeq 1/\sqrt{2\nu_{V_A}}=0{,}316227 \quad \Rightarrow u(u(V_A))\cong0{,}03V$

C) V_B? $u(V_B)$ in notaz. concisa e 2 cifre

$u_r(R)=u(R)/R={}^{3\Omega}/_{100\Omega}=0{,}03$

$u_r(I)=U_r(I)/K=0{,}08/2=0{,}04$

$u_r(V_B)=\sqrt{0{,}03^2+0{,}04^2}=0{,}05$

$V_B=RI=100\Omega\cdot85mA=8{,}5V$

$\Rightarrow u(V_B)=0{,}05\cdot8{,}5V=0{,}425V \rightarrow u(V_B)=0{,}43V$

$V_B=8{,}50(43)V$

D) voltmetro integratore a doppia rampa

$V_R=-2{,}5V \quad u(V_R)=15\mu V$

$T_I=10T_{corr}=10\ {}^{1}/_{50Hz}=0{,}2s$

$f_c=100kHz \quad u_r(f_c)=5ppm=5\cdot10^{-6}$

$N_D=65000$

$V_C=?$

$T_D=T_cN_D={}^{1}/_{100\cdot\cancel{10^3}}\,s\cdot65\cancel{000}=0{,}65s$

$T_U=T_I=0{,}2s$

$\rightarrow V_C=-\frac{V_R}{T_U}T_D=\frac{2{,}5V}{0{,}2s}0{,}65=8{,}125V$

E) $u_r(V_C)=?$ $\quad V_C$?

$u_q(V_C)=-\frac{V_R}{T_U}\frac{T_c}{\sqrt{12}}=\frac{2{,}5V}{0{,}2s}\frac{10^{-5}s}{\sqrt{12}}=3{,}6\cdot10^{-5}V \qquad u_{rq}(V_R)={}^{3{,}6\cdot10^{-5}V}/_{8{,}125V}=0{,}44\cdot10^{-5}$

$u_r(N_D)=\frac{1}{N_D\sqrt{12}}=\frac{1}{65000\sqrt{12}}=4{,}4\cdot10^{-5} \quad u_r(N_D)=u_r(T_D)$

$u_r(T_c)=5\cdot10^{-6}$

$u_r(V_R)={}^{15\mu V}/_{2{,}5V}=6\cdot10^{-6}$

$V_C=8{,}125000(73)V$

$\Rightarrow u_r(V_C)=\sqrt{u_r^2(T_D)+u_r^2(V_R)}=9{,}0\cdot10^{-6}$

$u(V_C)=73\mu V$

F) compatibilità misure?

A e B) $|V_A-V_B|\le K\sqrt{u^2(V_A)+u^2(V_B)}$ $\quad |8{,}45-8{,}50|\le K\sqrt{0{,}1^2+0{,}43^2}$ $\quad \overline{0{,}05\le0{,}44K}^{K_{min}=0{,}11}$ $\Rightarrow K=1$ compatib. forte

A e C) $|8{,}45-8{,}125|\le K\sqrt{0{,}1^2+(73\cdot10^{-6})^2}$ $\quad 0{,}325\le K\,0{,}1$ $\Rightarrow K=4 \rightarrow$ incomp.

B e C) [...] $\quad K_{min}=0{,}88$ $\Rightarrow K=1 \rightarrow$ comp.

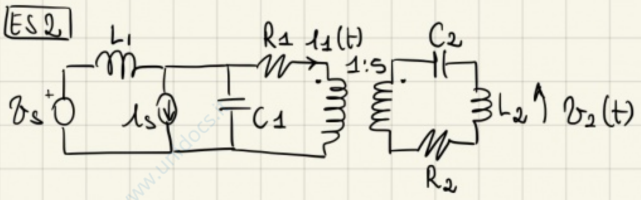
considero B e C misure più affidabili perché compatibili tra loro e perché C ha incertezza ≪ di A e B

G) miglior stima V? considerando sia le sole misure B e C, che tutte le misure A, B, C

la stima $V\cong V_C$ perché $u(V_C)\ll u(V_A), u(V_B)$ usando la formula V = ...

H) Verifica legge di Ohm

ES 2



$\omega = 100\ rad/s$

$v_s(t) = 20\cos(\omega t)\ V$

$i_s(t) = 1\sin(\omega t) A = 1\sin(\omega t - \pi/2) A$

$L_1 = 0{,}1\ H$ $C_2 = 10\ \mu F$

$C_1 = 2\ mF$ $L_2 = 10\ H$

$R_1 = 3\ \Omega$ $R_2 = 50\ \Omega$

A) Trasf circ nel dominio fasori

$\bar{V}_s = 20\ V$

$\bar{I}_s = 1(e^{-j\pi/2}) A = -j A$

$Z_{L1} = j\omega L = j10\ \Omega$

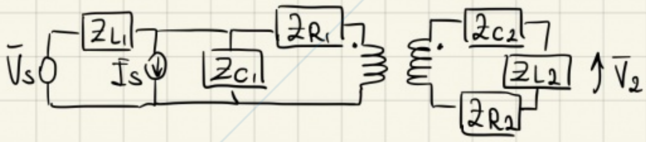
$Z_{C1} = 1/j\omega C = -j\ 1/100 \cdot 2 \cdot 10^{-3}\ \Omega = -j5\ \Omega$

$Z_{R1} = R_1 = 3\ \Omega$

$Z_{C2} = 1/j\omega C = -j/100 \cdot 10 \cdot 10^{-6}\ \Omega = -j1000\ \Omega = -j1K\Omega$

$Z_{R2} = R_2 = 50\ \Omega$

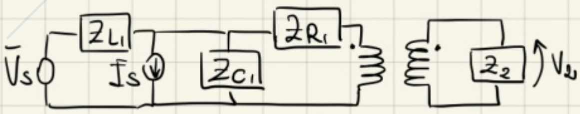
$Z_{L2} = j\omega L = j1000\ \Omega = j1K\Omega$

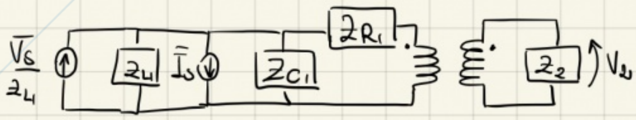


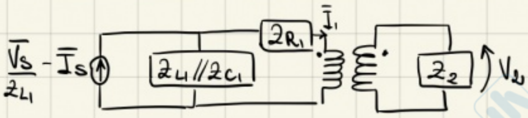
B) Z_2 ?

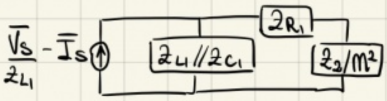
$Z_2 = Z_{C2} + Z_{R2} + Z_{L2} = -\cancel{j1000\ \Omega} + 50\ \Omega + \cancel{j1000\ \Omega} = 50\ \Omega$

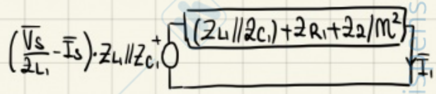
C) $I_1 = ?$ $V_2 = ?$

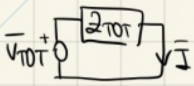












$$\bar{I}_1 = \frac{\left(\frac{\bar{V}_s}{Z_{L1}} - \bar{I}_s\right) \cdot Z_{L1}//Z_{C1}}{(Z_{L1}//Z_{C1}) + Z_{R1} + Z_2/m^2} = \frac{\bar{V}_{TOT}}{Z_{TOT}} = \frac{-10\ V}{(5-j10)\ \Omega} = \left(-\frac{2}{5} - \frac{4}{5}j\right) A = (-0{,}4 - 0{,}8j) A$$

$\frac{\bar{V}_s}{Z_{L1}} = -2j$

$Z_{L1}//Z_{C1} = \frac{j10\ \Omega(-j5\ \Omega)}{(j10 - j5\ \Omega)} = \frac{50}{j5}\ \Omega = -j10\ \Omega$

$Z_2/m^2 = 50\ \Omega/5^2 = 2\ \Omega$

$\Rightarrow \bar{V}_{TOT} = (-j2 + j)(-j10) V = -10\ V$

$\Rightarrow Z_{TOT} = (-10j + 3 + 2)\ \Omega = (5 - j10)\ \Omega$

$\bar{I}_2 = -\frac{\bar{I}_1}{m} = (0{,}08 + 0{,}16j) A \rightarrow \bar{V}_2 = -Z_{L2}\bar{I}_2 = -j1000\ \Omega(0{,}08 + 0{,}16j) A = (160 - j80) V$

D) $|\bar{I}_1|$? $\angle I_1$? $|\bar{V}_2|$? $\angle V_2$? $i_1(t)$? $v_2(t) = ?$

$|\bar{I}_1| = \sqrt{0{,}4^2 + 0{,}8^2} = 0{,}89$

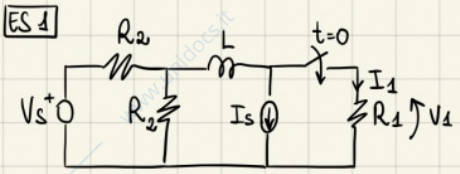
$\angle I_1 = \arctan 2(-0{,}4, -0{,}8) = -2{,}03444 = -116{,}5°$ $\Rightarrow i_1(t) = 0{,}89\cos(100t - 116{,}5°)$

$|\bar{V}_2| =$

$\angle \bar{V}_2 =$ [...]

11/09/21

ES 1

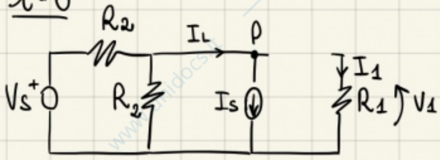


$V_s = 3V$
$I_s = 1A$
$R_1 = 4\Omega$
$R_2 = 2\Omega$
$L = 10mH$

A) eq. generale $V_1(t>0)$?
$V_1(t=0^+)$?

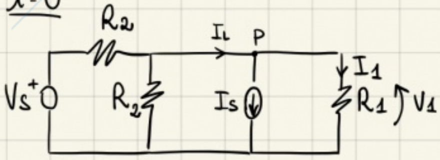
$$V_1(t>0) = [V_1(0^+) - V_1(\infty)]e^{-t/\tau} + V_1(\infty) \qquad \text{con } \tau = L/R_{EQ}$$

$t=0^-$



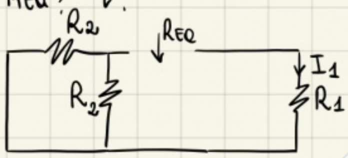
$V_1(0^-) = 0V$
KCL in P) $I_L(0^-) = I_s$
$I_L(0^-) = I_L(0^+)$ ← var. di stato $\rightarrow I_L(0^+) = I_s$

$t=0^+$



KCL in P) $I_1(0^+) = 0A \rightarrow V_1(0^+) = 0V$

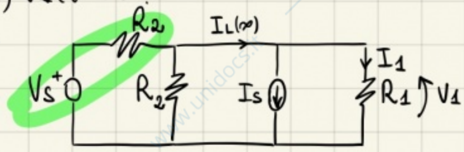
B) R_{EQ} ? τ ?



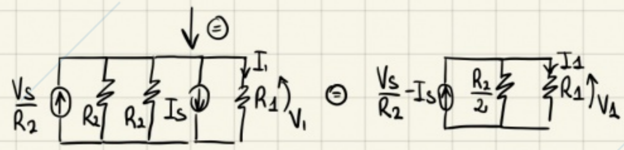
$$R_{EQ} = \underbrace{R_2 /\!/ R_2}_{R_2/2} + R_1 = 1\Omega + 4\Omega = 5\Omega$$

$$\tau = L/R_{EQ} = 10mH / 5\Omega = 2ms$$

C) $V_1(t=\infty)$?



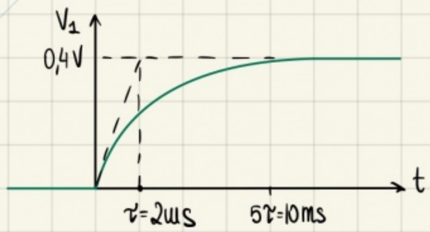
partit. di corr. $\rightarrow I_1 = \frac{R_2/2}{R_1 + R_2/2}\Big[\underbrace{\frac{V_s}{R_2} - I_s}_{\frac{3V}{2\Omega} - 1A = 0,5A}\Big] = \frac{1\Omega}{4\Omega + 1\Omega} \cdot 2,5A = \frac{1}{5} \cdot 2,5A = 0,1A$



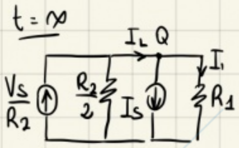
$V_1 = R_1 I_1 = 4\Omega \cdot 0,1A = 0,4V$

D) $V_1(t) = ?$ + grafico

$$V_1(t>0) = [V_1(0^+) - V_1(\infty)]e^{-t/\tau} + V_1(\infty)$$
$$= [0V - 0,4V]e^{-t/2ms} + 0,4V$$
$$= -0,4V e^{-t/2ms} + 0,4V$$



E) $t = \infty$



KCL in Q) $I_L(\infty) = I_s + I_1(\infty) = 1A + 0,1A = 1,1A$

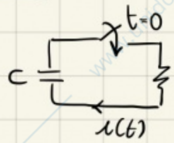
$$I_L(t) = [\overbrace{I_L(0^+)}^{=0} - I_L(\infty)]e^{-t/2ms} + I_L(\infty) = 1,1A(1 - e^{-t/2ms})$$

$I_L(t = 4ms) = 1,1A(1 - e^{-2}) = 0,95A$

$$E_L(t = 4ms) = \frac{1}{2} L I_L^2(t = 4ms) = \frac{1}{2} 10mH \cdot (0,95A)^2 = 4,5\ mJ$$

13/04/21

ES 1



$R = 2\,\Omega$

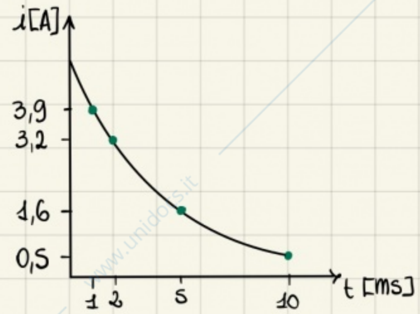
$i(1ms) = 3{,}9A$

$i(2ms) = 3{,}2A$

$i(5ms) = 1{,}6A$

$i(10ms) = 0{,}5A$

A) grafico quantitativo con punti sperimentali? ⊕ i(t) teorica a tratto continuo
equaz teoriche?



$i(\infty) = 0\,A \quad v_c(\infty) = 0V$

$v_c(t) = v_c(0)e^{-t/\tau}$

$i(t) = \underbrace{i(0^+)}\, e^{-t/\tau} \qquad \tau = RC$

$i(0^+) = v_c(0)/R$

B) x - legata a t } adimens. + grafico y(x) linearizzato
y - legata a i

$x = t/ms \quad \{1;2;5;10\}$ → relaz lineare x e y

$y = \ln[i(t)/A] \quad \{1{,}36;\ 1{,}16;\ 0{,}47;\ -0{,}69\}$

C) eq. retta di regressione? m? q? c? $v_c(0)$?

$m = -0{,}2196 \qquad q = 1{,}608$

$\ln(i(t)) = \ln(i(0^+)) - \frac{t}{\tau} \Rightarrow m = -1/\tau$

$q = \ln(i(0^+)) = \ln(v_c(0)/R)$ ⊕ ...

$\boxed{ES4}$

oscilloscopio dig: $f_c = 200MHz$, $N_{CH} = 2$
si vuole misurare [filtro passa-basso a singolo polo con banda passante $f_F = 2MHz$
usando generatore di sinusoidi: $V_{MAX} = 1V$, $f_s = 100kHz / 1GHz$
⊕ sovrapposta tens continua $V_{OFFSET} = \pm 0.5V$

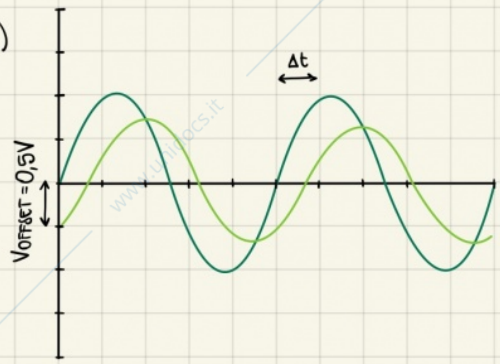
A) cosa limita f_{MAX} acquisibile dall'osc.? [freq di camp.: $f_{max} \leq f_c/2$
banda passante dei circ. analogici in ingresso: $f_{max} \leq B_{ANALOG.}$

B) modalità di misura (impostaz e scale) a seconda delle misure effettuate?

- si collega [l'uscita del generatore di sinusoide a CH1 dell'osc. e all'ingresso del filtro da misurare
  l'uscita del filtro a CH2
- gen di sin [V fissa
  f_s deve variare da 2-3 decadi in meno di f_F a 2/3 decadi in più di f_F (da 20-200kHz a 20-200MHz)
- accoppiamento AC per eliminare offset
- livello di zero a metà schermo per entrambi i canali
- Trigger su CH1 con slope + e livello 0V
- A_x deve essere sufficiente a vedere 1 intero periodo delle sinusoidi di ingresso e di uscita (isofrequenziali)
  ↳ deve essere cambiata ogni volta che si varia la frequenza della sinusoide
  es. $A_x = 2/10 \; 1/f_s$ → visualizzo 2 periodi
  CH1) $A_y = V_{max\,s}/4 = 1V/4 = 0,25V/div$ → $A_y = 0,5V$
  CH2) $A_y = \Delta V_{2pp}/8$ deve essere variata quando l'ampiezza del segnale trasmesso dal filtro varia

C) Si vuole visualizzare lo $\overbrace{\text{sfasamento}}^{\Delta t}$ indotto dal filtro alla $\underbrace{\text{freq. nominale del polo}}_{= \text{freq. del filtro}}$ (freq di taglio)
Tutte le imp? schermate corrisp?

Si imposta la sinusoide a f_F ($f = 2MHz$ → $T = 500ns$)
$A_x = 2T/10\,div = 100ns/div$ ← vedo 2 periodi
$A_{y1} = A_{y2} = A_y = V_{max\,s}/4 = 0,25V/div$ → $A_y = 0,5V$



$T_s = 500ns$
Alla freq del polo ci aspettiamo $\phi = -45°$
$\Delta\phi = -\frac{\Delta t}{T} \cdot 360°$ ⇒ $\Delta t = -\frac{\Delta\phi}{360} \cdot T = 62,5ns \simeq 0,6\,div_x$

D) Se il filtro avesse banda passante $B_F = 200MHz$ si potrebbe ancora effettuare la misura? cosa cambierebbe?

$f_{max} \leq f_c/2 = 200MHz/2 = 100MHz$ ⇒ sia CH1 che CH2 sarebbero distorti, cioè attenuati e sfasati
Per questa misura, ma l'ing. che l'uscita del filtro subirebbero (se i due canali sono identici) la stessa attenuaz e lo stesso sfasam.
↳ la misura è ancora poss. fino alle max freq acquisibili dal campionat. e per le quali le ampiezze visualizzate non siano troppo attenuate
Essendo il segnale da misurare sinusoidale (→ periodico) → è poss campionare i segnali in Tempo equivalente senza probl di aliasing

ES3

ⓐ pila a bottone da 1,5 V $V_A = 1{,}54321\,V$
ⓑ tens. di alimentaz. di rete V_B

VOLTMETRO A DOPPIA RAMPA range da ±20mV a ±20V (multipli 10x)
$n = 20$ cifre + 1 segno
$T_U = 200\,ms$
$f_C = 1MHz \pm 10\,Hz$
$V_{REF} = 381{,}47\,mV$ $u_r(V_{REF}) - 0{,}5\,ppm$

OSCILLOSCOPIO $N_{CH} = 2$
banda 60MHz
ADC FLASH $n = 8$
scale {1,2,5,10} da 5mV/div a 5V/div
da 10ns/div a 1s/div
calibratore int da 0-5V
sonde di ingr. passive 10x e 100x

A) Almeno 2 ragioni per cui non si può misurare la tens. di rete con il voltmetro?

- Adatto a misurare tens. continue o lentamente variabili (voltmetro lento) ($f_{CORR} = 50\,Hz$)
- dinamica max voltmetro : ±20V MA $V_{PP\,CORR} = 311V$

B) T_{mis}? di V_A con il voltmetro

$T_C = \frac{1}{f_C} = 1\mu s$
$T_{mis} = T_U + T_D$
$T_D = -\frac{V_A}{V_R} T_U = \frac{1{,}54321\,V}{381{,}47\,mV} T_U$] $\rightarrow T_{mis} = \left(1 + \frac{1{,}54321}{381{,}47} \cdot 10^3\right) T_U = 1{,}009\,s$

C) Perché la misura con il voltmetro a doppia rampa è insensibile a $u(f_C)$?

T_U e T_D misurati con lo stesso T_C $\left(V_X = -\frac{T_D}{T_U} V_R = -\frac{N_D \cancel{T_C}}{N_U \cancel{T_C}} V_R \right)$

D) $n_{CIFRE} = 9$ $V_{mis\,A} = ?$

$\Delta V = V_{max}/2^n = 2V/2^{20} = 1{,}9073486328125\,\mu V$
$V_{mis\,A} = \text{Int}\left\{\frac{V_A}{\Delta V}\right\} \Delta V = \underline{1{,}54320908\,V}$
$n_{CIFRE} = 9$

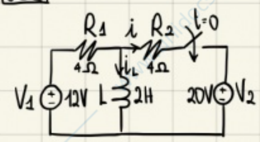
E) a V_A sovrapposto disturbo sinusoidale $V_{PP_D} = 20\,mV$ $f_D = 313\,Hz$
$r = ?$ $R_{dB} = ?$
si valuti il rapporto segnale – disturbo in potenza (in dB) sia prima che dopo l'integrazione

$r = \frac{\pi f_D T_I}{|\sin(\pi f_D T_I)|} \simeq 207$ con $T_I = T_U$

$R_{dB} = 20\log_{10}(r) \cong 46{,}3\,dB$
$(S/D)_{prima\,dB} = 10\log_{10}(V_A/V_{D\,EFF})^2 \simeq 37{,}8\,dB$
$V_{D\,EFF\,dopo} = V_{D\,EFF\,prima}/r \simeq 97\,\mu V$
$(S/D)_{dopo\,dB} = 10\log_{10}(V_A/V_{D\,EFF\,dopo})^2 \cong 250 \cdot 10^6$

12/01/22

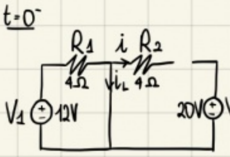
ES 1



A) $i(t)=?$ $i_L(0^+)=?$ $i_L(\infty)=?$

$i(t)=[i(0^+)-i(\infty)]e^{-t/\tau}+i(\infty)$ $\qquad \tau = L/R_{EQ}$

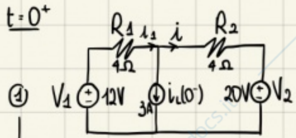
t=0⁻



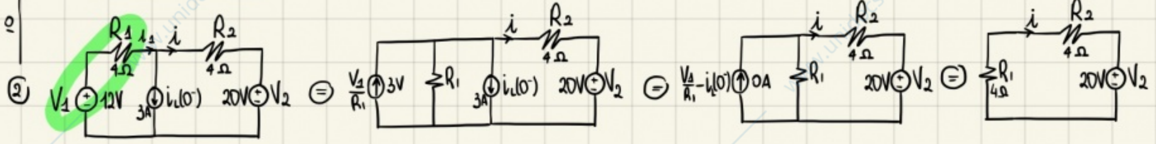
$i(0^-)=0V$ non è detto che $i(0^-)=i(0^+)$

$i_L(0^-)=V_1/R_1 = 12V/4\Omega = 3A = i_L(0^+)$

t=0⁺

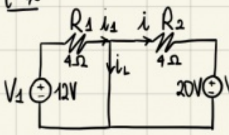


$\begin{cases} KCL)\ i=i_1-i_L \Rightarrow i_1=i+i_L \\ KVL)\ V_1-R_1i_1-iR_2-V_2=0 \end{cases} \Rightarrow V_1-R_1(i+i_L)-iR_2-V_2=0 \quad V_1-V_2-R_1i_L=i(R_1+R_2) \Rightarrow i(0^+)=\frac{V_1-V_2-R_1i_L}{R_1+R_2}=-2{,}5A$



$i(0^+)=-\frac{V_2}{R_1+R_2}=\frac{20V}{8\Omega}=-2{,}5A$

t=∞



$i(\infty)=-\frac{V_2}{R_2}=-5A$

$i_1(\infty)=\frac{V_1}{R_1}=3A$ $\Rightarrow i_L(\infty)=i_1(\infty)-i(\infty)=8A$

τ

$R_{EQ}=R_1//R_2=2\Omega \rightarrow \tau=L/R_{EQ}=1s$

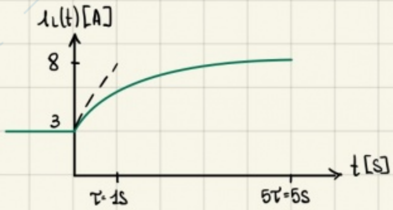
⇓

$i(t)=(-2{,}5A-5A)e^{-t/\tau}+5A=-4{,}5A\,e^{-t/1s}+5A$

$i_L(t)=(3A-8A)e^{-t/\tau}+8A=-5A\,e^{-t/1s}+8A$

B) grafico $i_L(t)$?

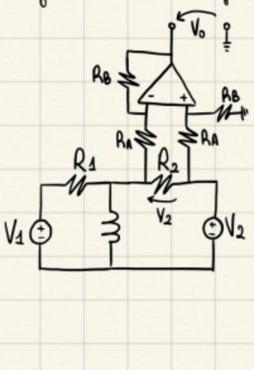
$E_L(t=2)=?$



$E_L(t=2)=\frac{1}{2}Li^2(2)=\frac{1}{2}2H\,[-5Ae^{-2}+8A]^2=53{,}6J$

C) per misurare V ai capi di R_2 ⇒ op amp differenziale $G=5\cdot10^{-3}$

disegno? V_{mis} a regime?



$V_{mis}=V_0=\frac{R_B}{R_A}V=GV=100\cdot10^{-3}V=-0{,}1V$

$V=R_2i(\infty)=4\Omega(-5A)=-20V$

15/04/20

ES 1

DAQ

$N_{CH} = 8$ single-ended (4 diff)

ADC ad approx succ. $\Delta_{ADC} = \pm 1V$

$n = 12 bit$

$f_c = 200 KSa/s$

Attenuatore in ingr. $A = 0{,}2 V/V$

$S_1)$ ϑ_1 $\Delta_1 = [-40°C, +400°C]$

$10 \mu V/K = 10^{-6} V/K = 10^{-6} V/°C$

uscita nulla a $273K = 0°C$

$S_2)$ ϑ_2 segnale audio right $\Delta_2 = \pm 3V$

$S_3)$ ϑ_3 segnale audio left $\Delta_3 = \pm 3V$

$S_4)$ ϑ_4 tens di rete attenuato di 80dB

$S_5)$ ϑ_5 sinusoide $V = \pm 1V$ $f = 0{,}5 MHz$

A) Quali è possibile acquisire?

$S_1)$ $\Delta_1 = [-0{,}4, +4] mV < \Delta_{ADC}$ → non serve attenuatore — OK

presumibilmente varia lentamente → non pone limiti di velocità per l'acquis.

S_2 e S_3) + attenuatore $\Delta_2 = \Delta_3 = \pm 0{,}6 < \Delta_{ADC}$ — OK

banda audio $\leq 20 kHz$ → $f_c \geq 2 \cdot 20 kHz = 40 kHz < f_{c\,ADC}$

$S_4)$ $f_4 = 50 Hz$ → $f_c \geq 100 Hz < f_{c\,ADC}$ — OK

anche l'ampiezza rientra nella dinamica dell'ADC

$S_5)$ $2f_5 > f_{ADC}$ → non è possibile acquisire S_5

S_1, S_2, S_3, S_4 possono essere tutti acq. in modalità diff

$f_{1,2,3,4} = f_{ADC}/4 = 200 KSa/s / 4 = 50 KSa/s > f_{c_1}, f_{c_2}, f_{c_3}, f_{c_4}$

B) Scegliere i guadagni ottimali $G(dB) = [0, \pm 6, \pm 10, \pm 20, \pm 40]$

$G = [1; 2; 1/2; 3; 1/3; 10; 1/10; 100, 1/100]$

$S_1)$ $G = 100 = 40dB$ → $\Delta_1 = [-0{,}04, +0{,}4] V$

$S_{2,3})$ $G = 1/3 = -10dB$ → $\Delta_{2,3} = \pm 1V$

$S_4)$ $V_{max} = 311V \cdot 10^{-4} = 0{,}0311V$ → $G_4 = 10 = 20dB$ → $\Delta_4 = \pm 0{,}311V$

C) Di quanto risultano sovracampl. i segnali audio?

$f_{c\,MIN_{2,3}} = 40 KHz$ $\quad$ $f_c = 50 KHz$ $\quad$ $K_{sc} = f_c / f_{c\,MIN_{2,3}} = 50/40 = 1{,}25 = +25\%$

D) $u(V_{max\,2,3}) = ?$ $\quad$ $u_r(V_{max\,2,3}) = ?$

$$u(V_{max\,2,3}) = \frac{\Delta_{ADC}}{2^n G} \frac{1}{\sqrt{12}} = \frac{2}{2^{12} \cdot 1/3} \cdot \frac{1}{\sqrt{12}} = 4{,}2 \cdot 10^{-4} V \qquad u_r(V_{max\,2,3}) = \frac{u(V_{max_{2,3}})}{V_{max_{2,3}}} = \frac{4{,}2 \cdot 10^{-4} V}{3V} = 1{,}4 \cdot 10^{-4}$$

E) $V_{N\,eff_{int}} = 375 \mu V = 375 \cdot 10^{-6} V$ ⇒ $\sigma^2_N = V^2_N = 1{,}41 \cdot 10^{-7} V^2$

$$\left.\begin{array}{l} \sigma^2_N = V^2_N = 1{,}41 \cdot 10^{-7} V^2 \\ \sigma^2_q = u^2_q = \left[\frac{\Delta_{ADC}}{2^n} \frac{1}{\sqrt{12}}\right]^2 = (1{,}41 \cdot 10^{-4} V)^2 = 1{,}9881 \cdot 10^{-8} V^2 \end{array}\right] \Rightarrow n_E = n - \frac{1}{2} \log_2 \left(1 + \frac{\sigma^2_N}{\sigma^2_Q}\right) = 12 - 1{,}5 = 10{,}5 bit$$

F) $V_{N\,eff\,EXT_1} = 375 \mu V$ → $V_{N\,eff\,int} = V_{N\,EXT_1} G_1 = 37500 \mu V$ ⇒ $\sigma^2_N = V^2_N = 1{,}41 \cdot 10^{-3}$ ⇒ $n_E = n - \frac{1}{2} \log_2 \left(1 + \frac{\sigma^2_N}{\sigma^2_Q}\right) = 12 - 8 = 4 bit$