ELETTRONICA ANALOGICA prof. MARCONCINI

Nozioni utili (da Elettrotecnica)

$$I = \frac{dQ}{dt}$$

$$\mathcal{L}_{AB} = \int_A^B \vec{F} \cdot d\vec{r} = U_A - U_B$$

$$V = \frac{U}{Q}$$

$$\vec{E} = \frac{\vec{F}}{Q}$$

$$\int_A^B \vec{E} \cdot d\vec{r} = V_A - V_B$$

$1.6 \times 10^{-19} J = 1 eV$ energia per spostare una carica elementare da un punto da un altro che differisca per una differenza di potenziale di 1 Volt

I gen. controllati sono dei gen. in cui il valore impresso non è costante, ma dipende da valori di tensione e corrente di altre parti del circuito.

Resistore



$V_{AB} = RI$ (Se $I>0$ scorre nel verso ipotizzato; se $I<0$ scorre nel verso opposto)

$V_{AB} = V_A - V_B$

se $I>0$ $\Rightarrow V_{AB} = RI > 0$

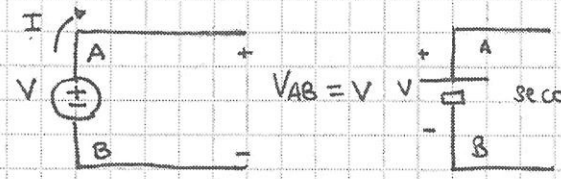
$R>0$ per definizione $\Rightarrow V_A > V_B$

$P_{diss} = RI^2$ → Effetto Joule

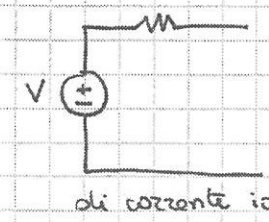
$U_A - U_B = E_{diss}$

• GENERATORI NON CONTROLLATI •

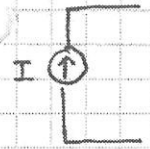
di tensione ideale



di tensione reale

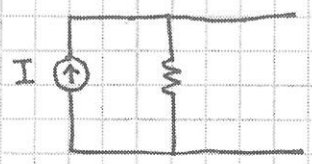


di corrente ideale

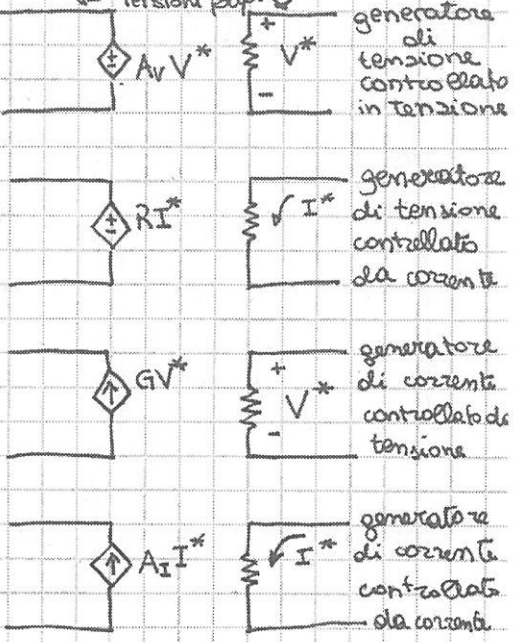


genera una corrente I costante indipendente dal valore della tensione ai suoi capi

di corrente reale



• GENERATORI CONTROLLATI •



• CAPACITORI •



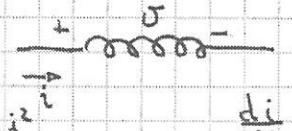
$C = \frac{Q}{v} \Rightarrow Q = C \cdot v$

$$v = \frac{Q}{C} = \frac{1}{C}\int i\,dt$$

$$i = \frac{dQ}{dt} = C\frac{dv}{dt}$$

$$E_C = \frac{1}{2} C v^2$$

• INDUTTORE •



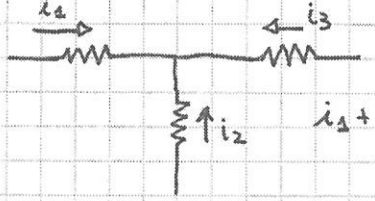
$\phi = Li$

$v = \frac{d\phi}{dt} = L\frac{di}{dt}$

$E_m = \frac{1}{2} L i^2$

$\frac{di}{dt} = \frac{v}{L} \rightarrow i = \frac{1}{L}\int v\,dt$

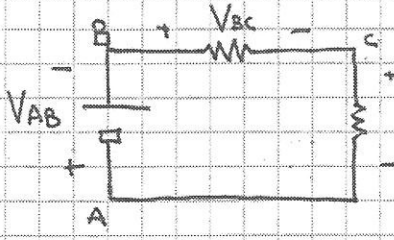
~ PRIMO PRINCIPIO DI KIRCHHOFF



$i_1 + i_2 + i_3 = 0$

Deriva dal principio di cons. della carica. $\sum I$ entranti in un nodo $= \emptyset$ (1)

• SECONDO PRINCIPIO DI KIRCHHOFF •



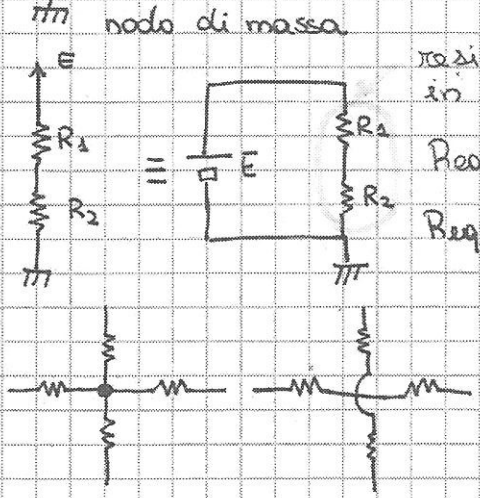
La somma di tutte le cadute di tensione prese con la stessa polarità, è NULLA.

[L'energia generata dal generatore si conserva nella maglia]

$V_{AB} + V_{BC} + V_{CA} = \phi$

(infatti $V_A - V_B + V_B - V_C + V_C - V_A = 0$)

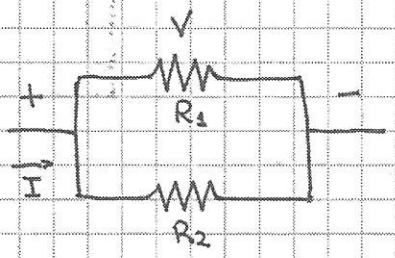
Riguardo alla simbologia:



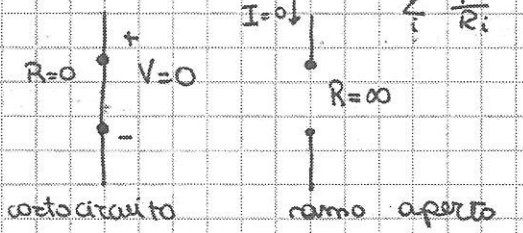
resistenze in serie

$R_{eq} = R_1 + R_2$

$R_{eq\ serie}: \sum_i R_i$



R_{eq} in parallelo $= \frac{1}{\sum_i \frac{1}{R_i}}$



Metodi per risolvere i circuiti utilizzando Kirchhoff:
- correnti di ramo
- correnti di maglia (o di corda)
- insiemi di taglio (e, come caso particolare, tensioni di nodo)

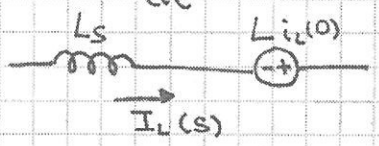
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Dominio di Laplace

$$\mathcal{L}\left[\frac{d}{dt}f(t)\right] = s\,\mathcal{L}[f(t)] - f(0)$$

$$\mathcal{L}\left[\int_{-\infty}^{t} f(\tau)\,d\tau\right] = \frac{\mathcal{L}[f(t)]}{s} + \frac{\int_{-\infty}^{0} f(\tau)\,d\tau}{s}$$

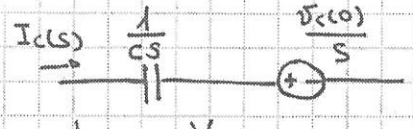
$$v_L(t) = L\frac{di_L(t)}{dt} \rightarrow V_L(s) = L[sI_L(s) - i_L(0)] = LsI_L(s) - Li_L(0)$$



$$Z_L = Ls$$

$$v_C(t) = \frac{1}{C}\int_{-\infty}^{t} i_C(\tau)\,d\tau \rightarrow V_C(s) = \left[\frac{I_C(s)}{s} + \frac{\int_{-\infty}^{0} i_C(\tau)\,d\tau}{s}\right] =$$

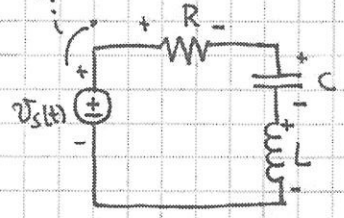
$$= \frac{I_C(s)}{Cs} + \frac{\frac{1}{C}\int_{-\infty}^{0} i_C(\tau)\,d\tau}{s} = \frac{I_C(s)}{Cs} + \frac{v_C(0)}{s}$$



$$Z_C = \frac{1}{Cs}$$

Se voglio lavorare in s e non nel tempo sostituisco il condensatore con uno di capacità $\frac{1}{Cs}$ e aggiungo un generatore

$$v_R(t) = Ri_R(t) \rightarrow V_R(s) = RI_R(s) \rightarrow Z_R = R$$



$$-v_s(t) + Ri + \frac{1}{C}\int_{-\infty}^{t} i(\tau)\,d\tau + L\frac{di}{dt} = 0$$

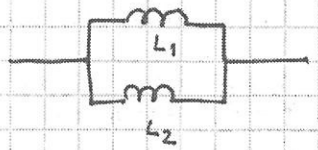
$$v_s(t) = Ri + \frac{1}{C}\int_{-\infty}^{t} i(\tau)\,d\tau + L\frac{di}{dt}$$

INDUTTANZA (sL)

$$V_s(s) = RI + \frac{1}{Cs}I + LsI$$



$Z_{eq\ serie} = sL_{eq\ serie}$ dove $L_{eq\ serie} = L_1 + L_2$



$$Z_{eq\ parallelo} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}} = \frac{1}{\frac{1}{s}\left(\frac{1}{L_1} + \frac{1}{L_2}\right)} = s\,\frac{1}{\frac{1}{L_1} + \frac{1}{L_2}} =$$

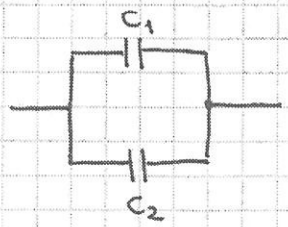
$$= sL_{parallelo}$$

CAPACITÀ



$$Z_{eq\ serie} = Z_1 + Z_2 = \frac{1}{sC_1} + \frac{1}{sC_2} = \frac{1}{s}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) =$$

$$= \frac{1}{sC_{eq\ serie}} \qquad C_{eq\ serie} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$



$$Z_{eq\ parallelo} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}} = \frac{1}{sC_1 + sC_2} = \frac{1}{s\,C_{eq\ parallelo}}$$

$$C_{eq\ parallelo} = C_1 + C_2$$

$Z_L = sL$ → nel dominio di Fourier $Z_L = j\omega L$

per $\omega = 0$ $Z_L = 0$ corto circuito

per $\omega = \infty$ $Z_L = \infty$ ramo aperto

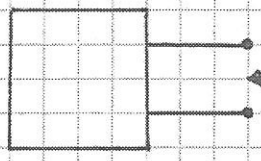
$Z_C = \frac{1}{sC}$ → nel dominio di Fourier $Z_C = \frac{1}{j\omega C}$

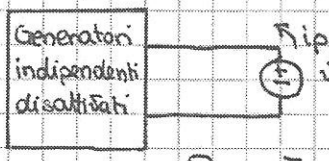
per $\omega = 0$ $Z_C = \infty$ ramo aperto

per $\omega = \infty$ $Z_C = 0$ corto circuito

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Resistenza vista (e in generale impedenza vista)

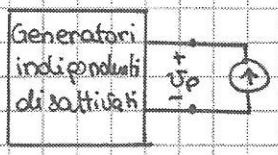




→ generatori di tensione sostituiti da cortocircuiti

→ generatori di corrente sostituiti da rami aperti

$R_V = \frac{v_p}{i_p}$

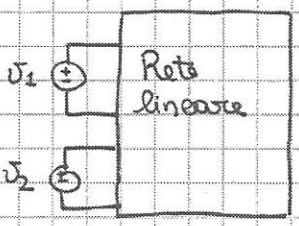


$R_V = \frac{v_p}{i_p}$

Nel caso in cui disattivo il gen. di tensione, ho un cortocircuito, la diff. di potenziale fra due punti è nulla, se $R=0 \rightarrow V=0$ $(I \neq 0)$ per la corrente significa sostituirlo con un ramo aperto e avrà $I=0$ in quel filo $(V \neq 0)$ oppure si può pensare a $R = +\infty$

Teoremi validi per reti lineari

Sovrapposizione degli effetti

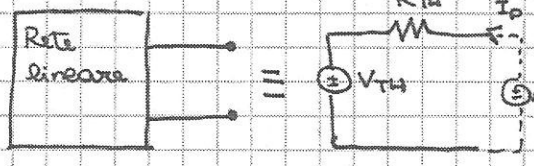


Si possono determinare gli effetti (tensioni e correnti) dato da sue cause (GENERATORI), sovrapponendo l'effetto prodotto da ciascuno di essi

→ I generatori sono indipendenti

→ I generatori possono agire uno alla volta

Equivalente di Thevenin



V_{TH} = Tensione a vuoto

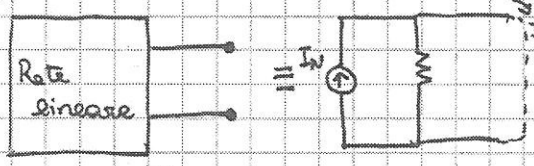
R_{TH} = resistenza vista

è la resist. vista tra i terminali a sx disattivando i gen. ind.

A sx lasciando tutto il resto inalterato, ma a vuoto (terminali staccati) senza nessun carico attaccato

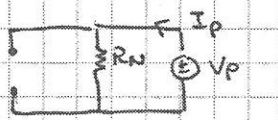
$R_V = \frac{V_p}{I_p} = \frac{V_p}{V_p / R_{TH}} = R_{TH}$

Equivalente di Norton



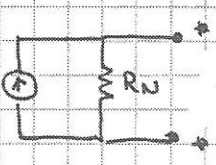
$I_{cc} = I_N$: corrente di cortocircuito → $I_{cc} = I_N$

R_N : resistenza vista = R_{TH}



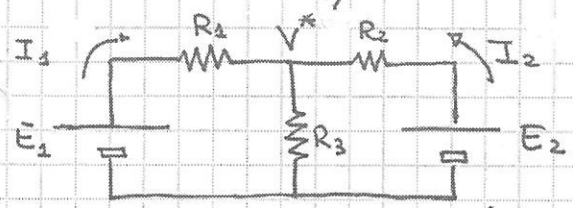
$R_V = \frac{V_p}{I_p} = \frac{V_p}{V_p / R_N} = R_N$

I_N disattivato



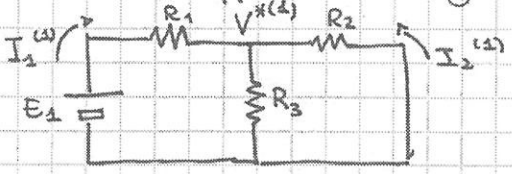
$I_{cc} = I_N \frac{R_N}{R_N} = I_N$

→ ESEMPIO: → (misurata rispetto al modo inferiore)



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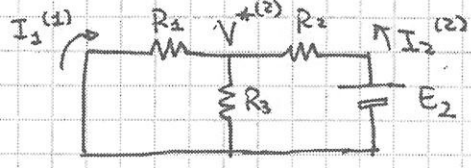
Con la sovrapposizione degli effetti (disattivo E_2):



$$I_1^{(1)} = \frac{E_1}{R_1 + (R_2 /\!/ R_3)}$$

$$V_A^{(1)} = I_A^{(1)} (R_2 /\!/ R_3) = E_1 \frac{R_2 /\!/ R_3}{R_1 + R_2 /\!/ R_3}$$

ora disattivo E_1



$$I_2^{(2)} = \frac{E_2}{R_2 + (R_1 /\!/ R_3)}$$

$$V^{*(2)} = E_2 \frac{R_1 /\!/ R_3}{R_2 + (R_1 /\!/ R_3)}$$

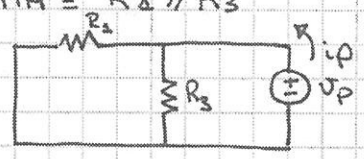
$$V^* = V^{*(1)} + V^{*(2)} = E_1 \frac{R_2 /\!/ R_3}{R_1 + (R_2 /\!/ R_3)} + E_2 \frac{R_1 /\!/ R_3}{R_2 + (R_1 /\!/ R_3)}$$

Con il teorema di Thevenin

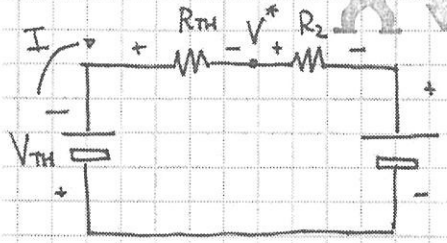


$$V_{TH} = E_1 \frac{R_3}{R_1 + R_3}$$

$$R_{TH} = R_1 /\!/ R_3 \qquad i_p = \frac{v_p}{R_1 /\!/ R_3} \rightarrow \qquad \frac{v_p}{i_p} = R_1 /\!/ R_3$$



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$$-V_{th} + R_{TH} I + R_2 I + E_2 = 0$$

$$I = \frac{V_{Th} - E}{R_{TH} + R_2}$$

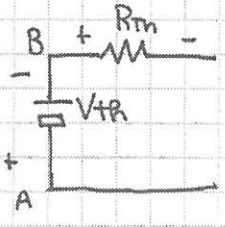
$$V^* = V_{Th} - R_{Th} I = V_{TH} - \frac{R_{th}}{R_{Th} + R_2} (V_{th} - E)$$

oppure $V^* = E_2 + R_2 I = E_2 + \frac{R_2}{R_{th} + R_2} (V_{th} - E)$

perché $V^* = V_C - V_A$

$$V_C = V_A + V_{BA} + V_{CB} = V_A + V_{TH} - R_{th} I \rightarrow V^* = V_C - V_A = V_{th} - R_{th} I$$

oppure



$$V_{AB} + V_{BC} + V_{CA} = 0$$

$$-V_{TH} + R_{th} I + V^* = 0$$

$$V^* = V_{th} - R_{th} I$$