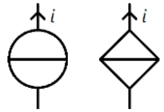
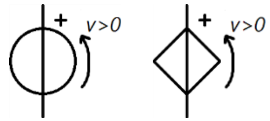
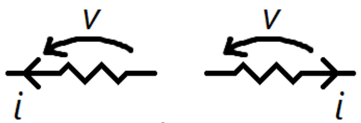
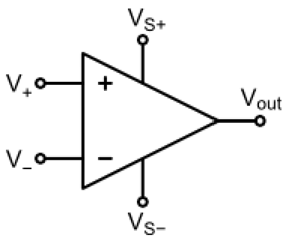
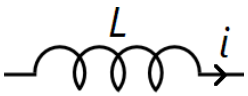
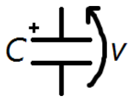
<u>**Bipoli**</u>	**Simbolo**	**Relazione costitutiva**	**Casi particolari**
Generatore di corrente $i(t) = \frac{dq(t)}{dt}$		$i = \text{cost.}\ \forall v$	circuito aperto: $i = 0\ \forall v$
Generatore di tensione $V(\vec{r}) = \frac{U(\vec{r})}{q}$		$v = \text{cost.}\ \forall i$	cortocircuito: $v = 0\ \forall i$
Resistore $R = \rho \cdot {}^{l}/_{A}$	 generatori utilizzatori	legge di Ohm: $v = R \cdot i$	circuito aperto: $R \to +\infty$ cortocircuito: $R = 0$
Amplificatore operazionale $v_0 = Av_d,\ v_d = v_+ - v_-$		amplificatore ideale: $\begin{cases} A \to +\infty \Rightarrow v_+ = v_- \\ R_i \to +\infty \Rightarrow i_+ = i_- = 0 \end{cases}$	invertente: $A = -\frac{R_F}{R_i} < 0$ non invertente: $A = \mu = 1 + \frac{R_F}{R_i} > 0$ con guadagno unitario: $A = 0 \Rightarrow v_0 = v_d = 0$
Induttore $\varphi(t) = L \cdot i(t),\ L = \frac{\mu s}{2\pi r} N^2$		$v(t) = L\frac{di(t)}{dt}$	cortocircuito: $i = \text{cost.} \Rightarrow v = 0$
Conduttore $q(t) = C \cdot v(t),\ C = \frac{\varepsilon A}{d}$		$i(t) = C\frac{dv(t)}{dt}$	circuito aperto: $v = \text{cost.} \Rightarrow i = 0$

Rappresentazioni dei doppi bipoli	Relazione costitutiva	Matrice		Condizione di reciprocità
su base corrente $v_1, v_2 = f(i_1, i_2)$	$\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} = R \begin{pmatrix} i_1 \\ i_2 \end{pmatrix}$	$R_{11} = {}^{v_1}/_{i_1}\Big\vert_{i_2=0}$	$R_{12} = {}^{v_1}/_{i_2}\Big\vert_{i_1=0}$ (trans-resistenza)	$R_{21} = R_{12}$
		$R_{21} = {}^{v_2}/_{i_1}\Big\vert_{i_2=0}$ (trans-resistenza)	$R_{22} = {}^{v_2}/_{i_2}\Big\vert_{i_1=0}$	
su base tensione $i_1, i_2 = f(v_1, v_2)$	$\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = G \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$	$G_{11} = {}^{i_1}/_{v_1}\Big\vert_{v_2=0}$	$G_{12} = {}^{i_1}/_{v_2}\Big\vert_{v_1=0}$ (trans-conduttanza)	$G_{21} = G_{12}$
		$G_{21} = {}^{i_2}/_{v_1}\Big\vert_{v_2=0}$ (trans-conduttanza)	$G_{22} = {}^{i_2}/_{v_2}\Big\vert_{v_1=0}$	
ibrida $v_1, i_2 = f(i_1, v_2)$	$\begin{pmatrix} v_1 \\ i_2 \end{pmatrix} = H \begin{pmatrix} i_1 \\ v_2 \end{pmatrix}$	$H_{11} = {}^{v_1}/_{i_1}\Big\vert_{v_2=0}$ (resistenza equivalente)	$H_{12} = {}^{v_1}/_{v_2}\Big\vert_{i_1=0}$ (guadagno in tensione)	$H_{12} = -H_{21}$
		$H_{21} = {}^{i_2}/_{i_1}\Big\vert_{v_2=0}$ (guadagno in corrente)	$H_{22} = {}^{i_2}/_{v_2}\Big\vert_{i_1=0}$ (conduttanza equivalente)	
di trasmissione $v_1, i_1 = f(v_2, -i_2)$	$\begin{pmatrix} v_1 \\ i_1 \end{pmatrix} = T \begin{pmatrix} v_2 \\ -i_2 \end{pmatrix}$	$T_{11} = A = {}^{v_1}/_{v_2}\Big\vert_{i_2=0}$	$T_{12} = B = {}^{v_1}/_{-i_2}\Big\vert_{v_2=0}$	$\det(T) = 1$
		$T_{21} = C = {}^{i_2}/_{v_2}\Big\vert_{i_2=0}$	$T_{22} = D = {}^{i_1}/_{-i_2}\Big\vert_{v_2=0}$	

<table>
<tr><td colspan="2" rowspan="3"><u>Legge di Ohm</u>
(nel dominio dei fasori)</td><td>$V = Z \cdot I$</td><td>$I = Y \cdot V$</td></tr>
<tr><td>$Z = R + jX$ (impedenza)</td><td>$Y = {}^{1}/_{Z} = G + jB$ (ammettenza)</td></tr>
<tr><td>• $\mathrm{Re}\{Z\} = R = {}^{V_M}/_{I_M}$ (resistenza)
• $\mathrm{Im}\{Z\} = X = \theta_v - \theta_i$ (reattanza)</td><td>• $\mathrm{Re}\{Y\} = G = \frac{R}{R^2+X^2} = {}^{I_M}/_{V_M}$ (conduttanza)
• $\mathrm{Im}\{Y\} = B = -\frac{X}{X^2+R^2} = \theta_i - \theta_v$ (suscettanza)</td></tr>
<tr><td>Bipoli resistivi
$\begin{cases} X = 0 \\ B = 0 \end{cases}$</td><td>resistore</td><td>$Z = R$</td><td>$Y = G$
$G = \frac{1}{R}$</td></tr>
<tr><td rowspan="2">Bipoli reattivi
$\begin{cases} R = 0 \\ G = 0 \end{cases}$</td><td>condensatore</td><td>$Z = \frac{1}{j\omega C} = jX_C$
$X_C = -\frac{1}{\omega C}$</td><td>$Y = j\omega C = jB_C$
$B_C = -\frac{1}{X_C} = \omega C$</td></tr>
<tr><td>induttore</td><td>$Z = j\omega L = jX_L$
$X_L = \omega L$</td><td>$Y = \frac{1}{j\omega L} = jB_L$
$B_L = -\frac{1}{X_L} = -\frac{1}{\omega L}$</td></tr>
</table>

<table>
<tr><td rowspan="4"><u>Potenza</u>
(in regime sinusoidale)</td><td colspan="4">$S = \frac{1}{2} V \bar{I} = P + jQ$ (potenza complessa)</td></tr>
<tr><td colspan="2">$\lvert S \rvert = V_{\text{eff}} \cdot I_{\text{eff}}$ (potenza apparente)</td><td colspan="2">$\cos \angle S = \cos(\theta_v - \theta_i) = \cos\varphi$ (fattore di potenza)</td></tr>
<tr><td colspan="2">$\mathrm{Re}\{S\} = P = V_{\text{eff}} I_{\text{eff}} \cos\varphi$ (potenza attiva)</td><td colspan="2">$\mathrm{Im}\{S\} = Q = V_{\text{eff}} I_{\text{eff}} \operatorname{sen}\varphi$ (potenza reattiva)</td></tr>
<tr><td>$P = R I_{\text{eff}}^2$</td><td>$P = G V_{\text{eff}}^2$</td><td>$Q = X I_{\text{eff}}^2$</td><td>$Q = -B V_{\text{eff}}^2$</td></tr>
<tr><td>resistore
$P > 0$</td><td>$P = R I_{\text{eff}}^2$</td><td>$P = G V_{\text{eff}}^2$</td><td colspan="2">$\begin{cases} X = 0 \\ B = 0 \end{cases} \Rightarrow Q = 0$</td></tr>
<tr><td>condensatore
$Q < 0$</td><td colspan="2" rowspan="2">$\begin{cases} R = 0 \\ G = 0 \end{cases} \Rightarrow P = 0$</td><td>$Q = -\frac{1}{\omega C} I_{\text{eff}}^2$</td><td>$Q = -\omega C V_{\text{eff}}^2$</td></tr>
<tr><td>induttore
$Q > 0$</td><td>$Q = \omega L I_{\text{eff}}^2$</td><td>$Q = \frac{1}{\omega L} I_{\text{eff}}^2$</td></tr>
</table>

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<tr><td colspan="2">

<u>Circuiti RLC in evoluzione libera</u>

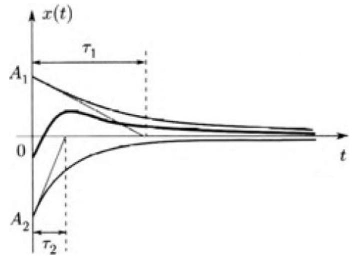
$$\frac{d^2x}{dt^2}+2\alpha\frac{dx}{dt}+{\omega_0}^2x=0$$

</td><td>$x(t)=A_1e^{s_1t}+A_2e^{s_2t}$</td><td>$\begin{cases}s_1=-\alpha+\sqrt{\alpha^2-{\omega_0}^2}\\ s_2=-\alpha-\sqrt{\alpha^2-{\omega_0}^2}\end{cases}$</td></tr>
<tr><td>

sovrasmorzato

$\alpha>\omega_0$

</td><td>

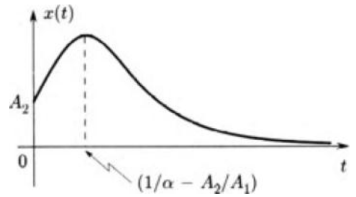


</td><td>$x(t)=A_1e^{s_1t}+A_2e^{s_2t}$</td><td>$s_2<s_1<0$</td></tr>
<tr><td>

con smorzamento critico

$\alpha=\omega_0$

</td><td>

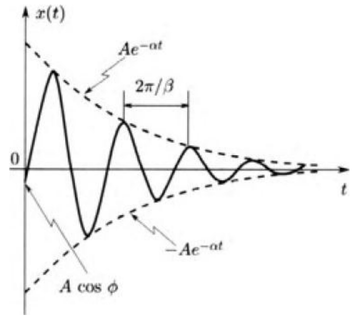


</td><td>$x(t)=(A_1t+A_2)e^{-\alpha t}$</td><td>$s_1=s_2=-\alpha=-\omega_0$</td></tr>
<tr><td>

sottosmorzato

$0<\alpha<\omega_0$

</td><td>



</td><td>

$x(t)=[A_1\cos(\beta t)+A_2\,\mathrm{sen}(\beta t)]e^{-\alpha t}$

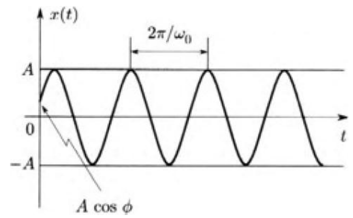
con $\beta=\sqrt{{\omega_0}^2-\alpha^2}$

</td><td>$\begin{cases}s_1=-\alpha+j\sqrt{{\omega_0}^2-\alpha^2}\\ s_2=-\alpha-j\sqrt{{\omega_0}^2-\alpha^2}\end{cases}$</td></tr>
<tr><td>

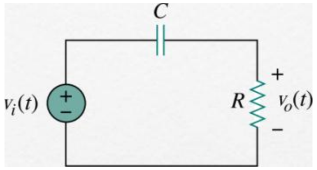
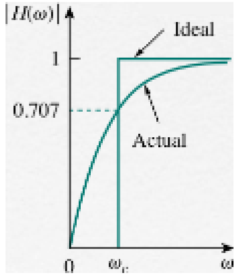
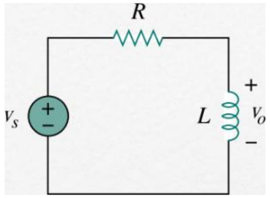
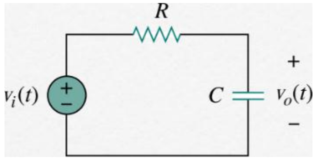
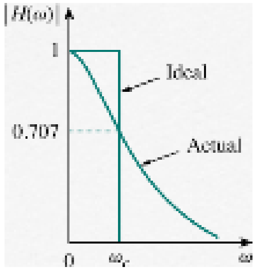
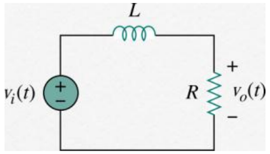
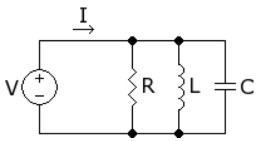
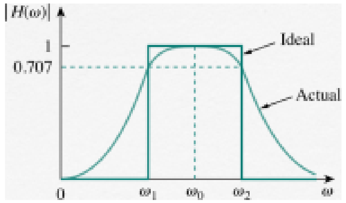
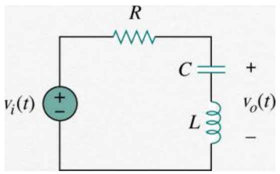
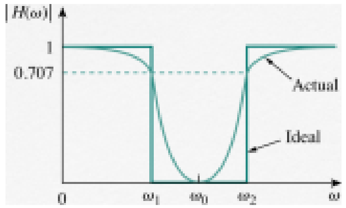
senza smorzamento

$\alpha=0$

</td><td>



</td><td>$x(t)=A_1\cos(\omega_0t)+A_2\,\mathrm{sen}(\omega_0t)$</td><td>$\begin{cases}s_1=+j\sqrt{{\omega_0}^2-\alpha^2}\\ s_2=-j\sqrt{{\omega_0}^2-\alpha^2}\end{cases}$</td></tr>
</table>

Filtri in regime sinusoidale			$\lvert H(j\omega)\rvert$ (risposta in ampiezza della funzione di trasferimento)		
passa-alto		circuito RC		$H(j\omega) = \dfrac{V_R}{V_i} = \dfrac{j\omega RC}{1 + j\omega RC}$	$\omega_C = \dfrac{1}{RC}$
		circuito RL			
passa-basso		circuito RC		$H(j\omega) = \dfrac{V_C}{V_i} = \dfrac{1}{1 + j\omega RC}$	
		circuito RL			
passa-banda		circuito RLC parallelo		$Z(j\omega) = \dfrac{V_o}{V_i} = \dfrac{1}{\frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)}$	$\omega_0 = \dfrac{1}{\sqrt{LC}}$ $Q = \omega_0 RC$
elimina-banda		circuito RLC serie		$Y(j\omega) = \dfrac{I_o}{V_i} = \dfrac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$	

<u>**Trasformata di Laplace**</u>	$F(s) = \mathcal{L}[f(t)] = \int_0^{+\infty} f(t)e^{-st}dt$
riscalamento	$\mathcal{L}[kf(t)] = kF(s)$
linearità	$\mathcal{L}[f_1(t) + f_2(t)] = F_1(s) + F_2(s)$
derivazione rispetto al tempo	$\mathcal{L}\left[\frac{df(t)}{dt}\right] = sF(s) - f(0)$
derivazione rispetto a s	$\mathcal{L}[t \cdot f(t)] = -\frac{dF(s)}{ds}$
traslazione rispetto al tempo	$\mathcal{L}[u(t-t_0) \cdot f(t-t_0)] = e^{-s \cdot t_0}F(s)$
trasformata di funzioni periodiche	$f(t)$ periodica di periodo T: $\mathcal{L}[f(t)] = F(s)\frac{1}{1-e^{-sT}}$

$$\mathcal{L}[e^{at}] = \frac{1}{s-a}$$