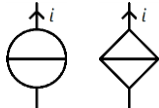
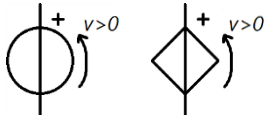
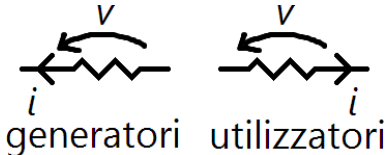
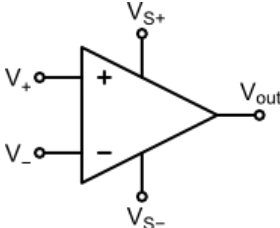
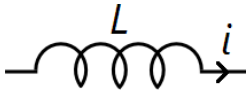
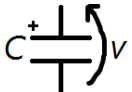


Bipoli	Simbolo	Relazione costitutiva	Casi particolari
Generatore di corrente $i(t) = \frac{dq(t)}{dt}$		$i = \text{cost. } \forall v$	circuito aperto: $i = 0 \forall v$
Generatore di tensione $V(\vec{r}) = \frac{U(\vec{r})}{q}$		$v = \text{cost. } \forall i$	cortocircuito: $v = 0 \forall i$
Resistore $R = \rho \cdot l/A$	 generatori utilizzatori	legge di Ohm: $v = R \cdot i$	circuito aperto: $R \rightarrow +\infty$ cortocircuito: $R = 0$
Amplificatore operazionale $v_0 = Av_d, v_d = v_+ - v_-$		amplificatore ideale: $\begin{cases} A \rightarrow +\infty \Rightarrow v_+ = v_- \\ R_i \rightarrow +\infty \Rightarrow i_+ = i_- = 0 \end{cases}$	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 $q(t) = C \cdot v(t), C = \frac{\epsilon A}{d}$		$i(t) = C \frac{dv(t)}{dt}$	circuito aperto: $v = \text{cost.} \Rightarrow i = 0$

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

		$V = Z \cdot I$		$I = Y \cdot V$			
		$Z = R + jX$ (impedenza)		$Y = 1/Z = G + jB$ (ammettenza)			
Legge di Ohm (nel dominio dei fasori)		<ul style="list-style-type: none"> • $\text{Re}\{Z\} = R = V_M/I_M$ (resistenza) • $\text{Im}\{Z\} = X = \theta_v - \theta_i$ (reattanza) 		<ul style="list-style-type: none"> • $\text{Re}\{Y\} = G = \frac{R}{R^2+X^2} = I_M/V_M$ (conduttanza) • $\text{Im}\{Y\} = B = -\frac{X}{X^2+R^2} = \theta_i - \theta_v$ (susceptanza) 			
Bipoli resistivi $\begin{cases} X = 0 \\ B = 0 \end{cases}$	resistore	$Z = R$		$Y = G$ $G = \frac{1}{R}$			
Bipoli reattivi $\begin{cases} R = 0 \\ G = 0 \end{cases}$		condensatore		$Z = \frac{1}{j\omega C} = jX_C$ $X_C = -\frac{1}{\omega C}$		$Y = j\omega C = jB_C$ $B_C = -\frac{1}{X_C} = \omega C$	
		induttore		$Z = j\omega L = jX_L$ $X_L = \omega L$		$Y = \frac{1}{j\omega L} = jB_L$ $B_L = -\frac{1}{X_L} = -\frac{1}{\omega L}$	

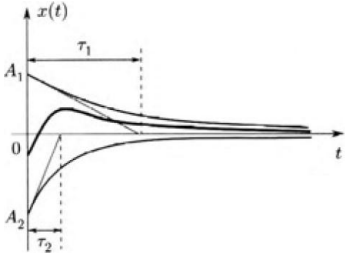
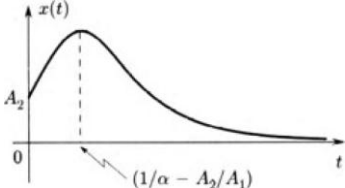
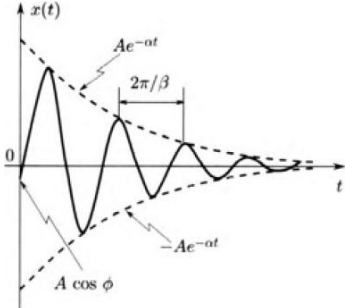
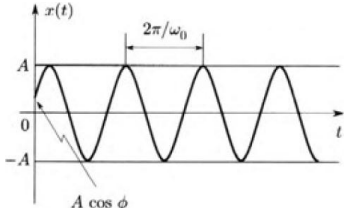
		$S = \frac{1}{2} V \bar{I} = P + jQ$ (potenza complessa)			
		$ S = V_{\text{eff}} \cdot I_{\text{eff}}$ (potenza apparente)		$\cos \angle S = \cos(\theta_v - \theta_i) = \cos \varphi$ (fattore di potenza)	
Potenza (in regime sinusoidale)		$\text{Re}\{S\} = P = V_{\text{eff}} I_{\text{eff}} \cos \varphi$ (potenza attiva)		$\text{Im}\{S\} = Q = V_{\text{eff}} I_{\text{eff}} \sin \varphi$ (potenza reattiva)	
		$P = RI_{\text{eff}}^2$	$P = GV_{\text{eff}}^2$	$Q = XI_{\text{eff}}^2$	$Q = -BV_{\text{eff}}^2$
resistore $P > 0$	$P = RI_{\text{eff}}^2$	$P = GV_{\text{eff}}^2$	$\begin{cases} X = 0 \\ B = 0 \end{cases} \Rightarrow Q = 0$		
condensatore $Q < 0$	$\begin{cases} R = 0 \\ G = 0 \end{cases} \Rightarrow P = 0$		$Q = -\frac{1}{\omega C} I_{\text{eff}}^2$	$Q = -\omega C V_{\text{eff}}^2$	
induttore $Q > 0$			$Q = \omega L I_{\text{eff}}^2$	$Q = \frac{1}{\omega L} V_{\text{eff}}^2$	

Circuiti RLC in evoluzione libera

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

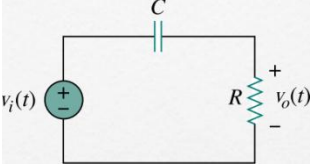
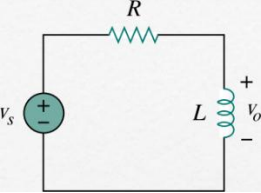
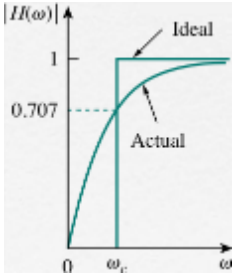
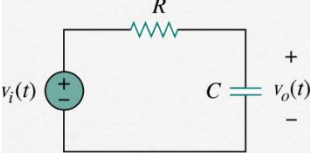
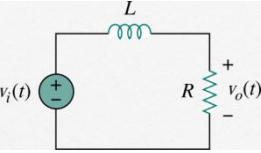
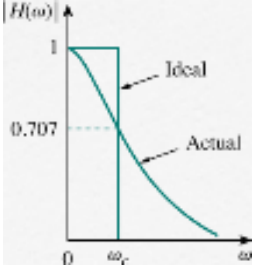
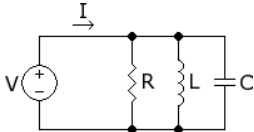
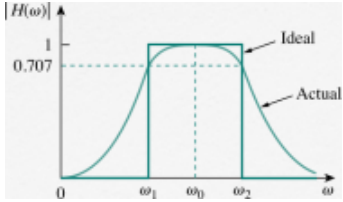
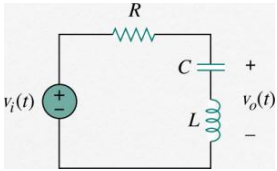
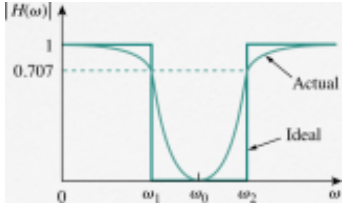
$$x(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

$$\begin{cases} s_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2} \\ s_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2} \end{cases}$$

<p>sovrasmorzato $\alpha > \omega_0$</p> 	$x(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$ $s_2 < s_1 < 0$
<p>con smorzamento critico $\alpha = \omega_0$</p> 	$x(t) = (A_1 t + A_2) e^{-\alpha t}$ $s_1 = s_2 = -\alpha = -\omega_0$
<p>sottosmorzato $0 < \alpha < \omega_0$</p> 	$x(t) = [A_1 \cos(\beta t) + A_2 \sin(\beta t)] e^{-\alpha t}$ $\text{con } \beta = \sqrt{\omega_0^2 - \alpha^2}$ $\begin{cases} s_1 = -\alpha + j\sqrt{\omega_0^2 - \alpha^2} \\ s_2 = -\alpha - j\sqrt{\omega_0^2 - \alpha^2} \end{cases}$
<p>senza smorzamento $\alpha = 0$</p> 	$x(t) = A_1 \cos(\omega_0 t) + A_2 \sin(\omega_0 t)$ $\begin{cases} s_1 = +j\sqrt{\omega_0^2 - \alpha^2} \\ s_2 = -j\sqrt{\omega_0^2 - \alpha^2} \end{cases}$

Filtri in regime sinusoidale

$|H(j\omega)|$ (risposta in ampiezza della funzione di trasferimento)

<p>passa-alto</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>circuito RC</p> </div> <div style="text-align: center;">  <p>circuito RL</p> </div> </div>	<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> $H(j\omega) = \frac{V_R}{V_i} = \frac{j\omega RC}{1 + j\omega RC}$ </div> </div> <div style="text-align: right; margin-top: 20px;"> $\omega_c = \frac{1}{RC}$ </div>
<p>passa-basso</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>circuito RC</p> </div> <div style="text-align: center;">  <p>circuito RL</p> </div> </div>	<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> $H(j\omega) = \frac{V_C}{V_i} = \frac{1}{1 + j\omega RC}$ </div> </div>
<p>passa-banda</p> <div style="text-align: center;">  <p>circuito RLC parallelo</p> </div>	<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> $Z(j\omega) = \frac{V_o}{V_i} = \frac{1}{R + j\left(\omega C - \frac{1}{\omega L}\right)}$ </div> </div> <div style="text-align: right; margin-top: 20px;"> $\omega_0 = \frac{1}{\sqrt{LC}}$ </div>
<p>elimina-banda</p> <div style="text-align: center;">  <p>circuito RLC serie</p> </div>	<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> $Y(j\omega) = \frac{I_o}{V_i} = \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$ </div> </div> <div style="text-align: right; margin-top: 20px;"> $Q = \omega_0 RC$ </div>

Trasformata di Laplace

$$F(s) = \mathcal{L}[f(t)] = \int_0^{+\infty} f(t)e^{-st} dt$$

riscaldamento	$\mathcal{L}[kf(t)] = kF(s)$
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 : $\mathcal{L}[f(t)] = F(s) \frac{1}{1 - e^{-sT}}$
$\mathcal{L}[e^{at}] = \frac{1}{s - a}$	