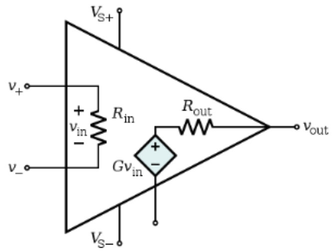


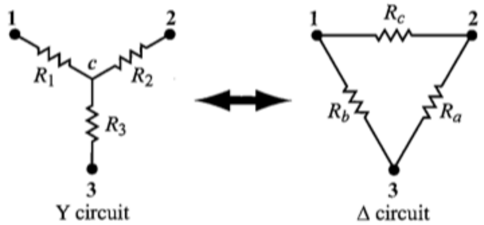
wheatstone

$$V_{out} \approx \frac{V_0}{4}\left(\frac{\Delta R}{R}\right)$$

resonance

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad \textbf{(RLC circuit).}$$

delta-wye

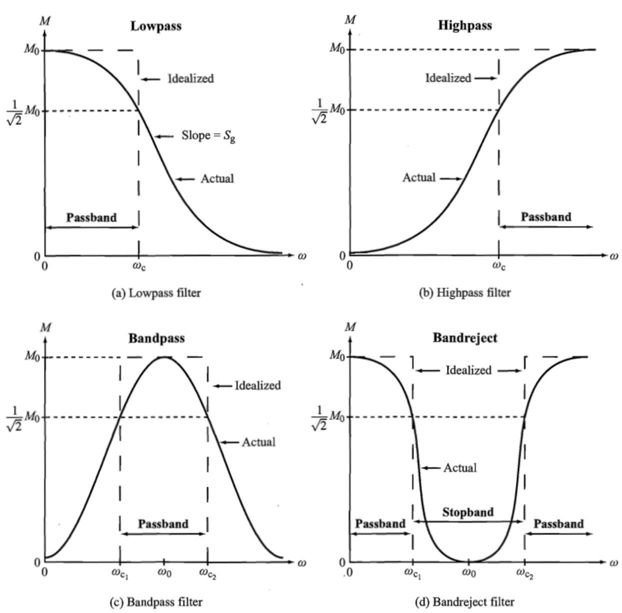


$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \qquad R_a = \frac{R_1R_2 + R_2R_3 + R_1R_3}{R_1}$$

equivalence

To Determine	Method	Can Circuit Contain Dependent Sources?	Relationship
v_{Th}	Open-circuit v	Yes	$v_{Th} = v_{oc}$
v_{Th}	Short-circuit i (if R_{Th} is known)	Yes	$v_{Th} = R_{Th} i_{sc}$
R_{Th}	Open/short	Yes	$R_{Th} = v_{oc}/i_{sc}$
R_{Th}	Equivalent R	No	$R_{Th} = R_{eq}$
R_{Th}	External source	Yes	$R_{Th} = v_{ex}/i_{ex}$
$i_N = v_{Th}/R_{Th}$; $R_N = R_{Th}$			

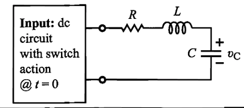
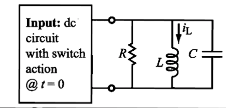
filters



(a) Lowpass filter (b) Highpass filter

(c) Bandpass filter (d) Bandreject filter

second order

Series RLC	Parallel RLC
	
Total Response	**Total Response**
Overdamped ($\alpha > \omega_0$)	**Overdamped** ($\alpha > \omega_0$)
$v_C(t) = v_C(\infty) + A_1e^{s_1t} + A_2e^{s_2t}$	$i_L(t) = i_L(\infty) + A_1e^{s_1t} + A_2e^{s_2t}$
$A_1 = \frac{\frac{1}{C}i_C(0) - s_2[v_C(0) - v_C(\infty)]}{s_1 - s_2}$	$A_1 = \frac{\frac{1}{L}v_L(0) - s_2[i_L(0) - i_L(\infty)]}{s_1 - s_2}$
$A_2 = \left[\frac{\frac{1}{C}i_C(0) - s_1[v_C(0) - v(\infty)]}{s_2 - s_1}\right]$	$A_2 = \left[\frac{\frac{1}{L}v_L(0) - s_1[i_L(0) - i_L(\infty)]}{s_2 - s_1}\right]$
Critically Damped ($\alpha = \omega_0$)	**Critically Damped** ($\alpha = \omega_0$)
$v_C(t) = v_C(\infty) + (B_1 + B_2t)e^{-\alpha t}$	$i_L(t) = i_L(\infty) + (B_1 + B_2t)e^{-\alpha t}$
$B_1 = v_C(0) - v_C(\infty)$	$B_1 = i_L(0) - i_L(\infty)$
$B_2 = \frac{1}{C}i_C(0) + \alpha[v_C(0) - v_C(\infty)]$	$B_2 = \frac{1}{L}v_L(0) + \alpha[i_L(0) - i_L(\infty)]$
Underdamped ($\alpha < \omega_0$)	**Underdamped** ($\alpha < \omega_0$)
$v_C(t) = v_C(\infty) + e^{-\alpha t}(D_1\cos\omega_d t + D_2\sin\omega_d t)$	$i_L(t) = i_L(\infty) + e^{-\alpha t}(D_1\cos\omega_d t + D_2\sin\omega_d t)$
$D_1 = v_C(0) - v_C(\infty)$	$D_1 = i_L(0) - i_L(\infty)$
$D_2 = \frac{\frac{1}{C}i_C(0) + \alpha[v_C(0) - v_C(\infty)]}{\omega_d}$	$D_2 = \frac{\frac{1}{L}v_L(0) + \alpha[i_L(0) - i_L(\infty)]}{\omega_d}$

Auxiliary Relations

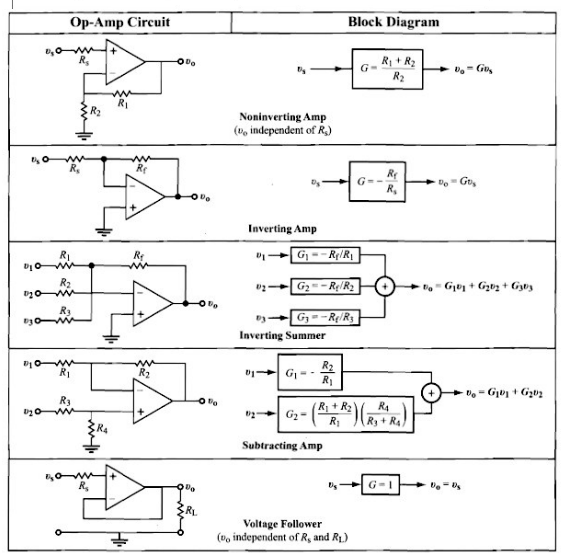
$$\alpha = \begin{cases} \frac{R}{2L} & \text{Series RLC} \\ \frac{1}{2RC} & \text{Parallel RLC} \end{cases} \qquad \omega_0 = \frac{1}{\sqrt{LC}} \qquad \omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

$$s_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2} \qquad s_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2}$$

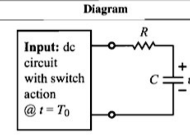
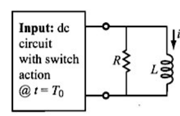
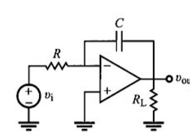
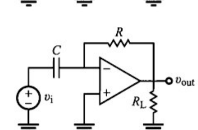
RLC & vars

Property	R	L	C
i–v relation	$i = \frac{v}{R}$	$i = \frac{1}{L}\int_{t_0}^{t} v\,dt' + i(t_0)$	$i = C\frac{dv}{dt}$
v-i relation	$v = iR$	$v = L\frac{di}{dt}$	$v = \frac{1}{C}\int_{t_0}^{t} i\,dt' + v(t_0)$
p (power transfer in)	$p = i^2R$	$p = Li\frac{di}{dt}$	$p = Cv\frac{dv}{dt}$
w (stored energy)	0	$w = \frac{1}{2}Li^2$	$w = \frac{1}{2}Cv^2$
Series combination	$R_{eq} = R_1 + R_2$	$L_{eq} = L_1 + L_2$	$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$
Parallel combination	$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$	$L_{eq} = \frac{L_1L_2}{L_1 + L_2}$	$C_{eq} = C_1 + C_2$
dc behavior	no change	short circuit	open circuit
Can v change instantaneously?	yes	yes	no
Can i change instantaneously?	yes	no	yes

op amp circuits



RLC transient responses

Circuit	Diagram	Response
RC		$v(t) = v(\infty) + [v(T_0) - v(\infty)]e^{-(t-T_0)/\tau}$ ($\tau = RC$) (for $t \geq T_0$)
RL		$i(t) = i(\infty) + [i(T_0) - i(\infty)]e^{-(t-T_0)/\tau}$ ($\tau = L/R$) (for $t \geq T_0$)
Ideal integrator		$v_{out}(t) = -\frac{1}{RC}\int_{t_0}^{t} v_i\,dt' + v_{out}(t_0)$
Ideal differentiator		$v_{out}(t) = -RC\frac{dv_i}{dt}$