

Sum of currents entering a node is zero (also holds for closed boundary)

Sum of voltages around a closed path is zero, or the sum of voltage drops is equal to the sum of voltage rises

$$\sum_{n=1}^N i_n = 0 \quad (\text{KCL})$$

$$\sum_{n=1}^N v_n = 0 \quad (\text{KVL})$$

Op-Amp Circuit	Block Diagram
	<p>Noninverting Amp (v_o independent of R_s)</p>
	<p>Inverting Amp</p>
	<p>Inverting Summer</p>
	<p>Subtracting Amp</p>
	<p>Voltage Follower (v_o independent of R_s)</p>

Figure 1: OpAmp Shortcuts

$$i^1 = i \quad i^2 = -1 \quad i^3 = -i \quad i^4 = 1$$

Euler's Formula:

$$e^{j\theta} = \cos(\theta) + j \sin(\theta)$$

$$\tan(\theta) = \frac{b}{a}$$

Amplitude: $c = \sqrt{a^2 + b^2}$, where:

$$\begin{cases} a &= c \cos(\theta) \\ b &= c \sin(\theta) \end{cases}$$

Rectangular Form:

$$n = a + jb$$

Important properties:

$$a + jb = ce^{j\theta}$$

Polar Form:

$$n = ce^{j\theta}$$

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)	$p = i^2 R$	$p = Li \frac{di}{dt}$	$p = Cv \frac{dv}{dt}$
w (stored energy)	0	$w = \frac{1}{2} Li^2$	$w = \frac{1}{2} Cv^2$
Series Combination	$R_{eq} = R_1 + R_2$	$L_{eq} = L_1 + L_2$	$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$
Parallel Combination	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$	$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$	$C_{eq} = C_1 + C_2$
DC Behavior	No change	Short circuit	Open circuit
Instantaneous v change?	Yes	Yes	No
Instantaneous i change?	Yes	No	Yes

$$i(t) = I_{\infty} + (I_o - I_{\infty})e^{-\frac{t}{\tau}}$$

$$v(t) = V_{\infty} + (V_o - V_{\infty})e^{-\frac{t}{\tau}}$$

$$\begin{matrix} RC & RL \\ \tau & RC & L/R \end{matrix}$$

$$p = P + P \cos(2\omega t) - Q \sin(2\omega t)$$

Where:

Average Power:

$$P = \frac{V_m I_m}{2}$$

Reactive Power:

$$P = \frac{V_m I_m}{2}$$

Power Factor

$$= \cos(90 + \theta_v - \theta_i)$$

IF positive, power factor is leading

IF negative, power factor is lagging

Maximum power transfer occurs when the Thevnin impedance is equal to the conjugate of the load impedance

Fourier Series:

$$f(t) = a_0 + \sum_{n=1}^{\infty} (a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t))$$

The coefficients of a Fourier series are:

$$\mathcal{F} \left\{ \begin{array}{l} a_0 = \frac{1}{T} \int_0^T f(t) dt \\ a_k = \frac{2}{T} \int_0^T f(t) \cos(k\omega_0 t) dt \\ b_k = \frac{2}{T} \int_0^T f(t) \sin(k\omega_0 t) dt \end{array} \right.$$

For an even function ($f(t) = f(-t)$):

$$\mathcal{F} \left\{ \begin{array}{l} a_0 = \frac{2}{T} \int_0^{\frac{T}{2}} f(t) dt \\ a_k = \frac{4}{T} \int_0^{\frac{T}{2}} f(t) \cos(k\omega_0 t) dt \\ b_k = 0 \end{array} \right.$$

For an odd function ($f(t) = -f(-t)$):

$$\mathcal{F} \left\{ \begin{array}{l} a_0 = 0 \\ a_k = 0 \\ b_k = \frac{4}{T} \int_0^{\frac{T}{2}} f(t) \sin(k\omega_0 t) dt \end{array} \right.$$

Table 13-2: Fourier series expressions for a select set of periodic waveforms.

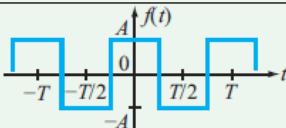
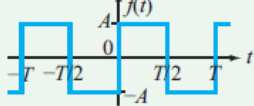
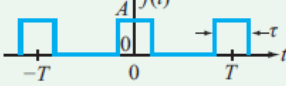
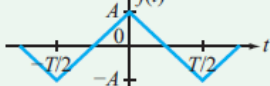
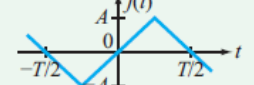
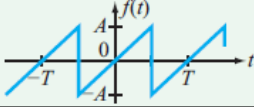
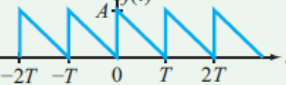
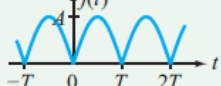
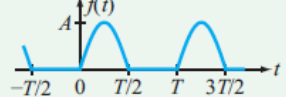
	Waveform	Fourier Series
1. Square Wave		$f(t) = \sum_{n=1}^{\infty} \frac{4A}{n\pi} \sin\left(\frac{n\pi}{2}\right) \cos\left(\frac{2n\pi t}{T}\right)$
2. Time-Shifted Square Wave		$f(t) = \sum_{n=1, n=\text{odd}}^{\infty} \frac{4A}{n\pi} \sin\left(\frac{2n\pi t}{T}\right)$
3. Pulse Train		$f(t) = \frac{A\tau}{T} + \sum_{n=1}^{\infty} \frac{2A}{n\pi} \sin\left(\frac{n\pi\tau}{T}\right) \cos\left(\frac{2n\pi t}{T}\right)$
4. Triangular Wave		$f(t) = \sum_{n=1, n=\text{odd}}^{\infty} \frac{8A}{n^2\pi^2} \cos\left(\frac{2n\pi t}{T}\right)$
5. Shifted Triangular Wave		$f(t) = \sum_{n=1, n=\text{odd}}^{\infty} \frac{8A}{n^2\pi^2} \sin\left(\frac{n\pi}{2}\right) \sin\left(\frac{2n\pi t}{T}\right)$
6. Sawtooth		$f(t) = \sum_{n=1}^{\infty} (-1)^{n+1} \frac{2A}{n\pi} \sin\left(\frac{2n\pi t}{T}\right)$
7. Backward Sawtooth		$f(t) = \frac{A}{2} + \sum_{n=1}^{\infty} \frac{A}{n\pi} \sin\left(\frac{2n\pi t}{T}\right)$
8. Full-Wave Rectified Sinusoid		$f(t) = \frac{2A}{\pi} + \sum_{n=1}^{\infty} \frac{4A}{\pi(1-4n^2)} \cos\left(\frac{2n\pi t}{T}\right)$
9. Half-Wave Rectified Sinusoid		$f(t) = \frac{A}{\pi} + \frac{A}{2} \sin\left(\frac{2\pi t}{T}\right) + \sum_{n=2, n=\text{even}}^{\infty} \frac{2A}{\pi(1-n^2)} \cos\left(\frac{2n\pi t}{T}\right)$

Figure 2: Common Fourier Series Table

The Fourier transform is written as:

$$F(\omega) = \mathcal{F}\{f(t)\} = \int_{-\infty}^{\infty} f(t)e^{-j\omega t} dt$$

The transforms below are with respect to $-\infty \leq t \leq \infty$, other boundaries must be recalculated

	$f(t)$	$F(\omega)$	
1	$e^{-at}u(t)$	$\frac{1}{a + j\omega}$	$a > 0$
2	$e^{at}u(-t)$	$\frac{1}{a - j\omega}$	$a > 0$
3	$e^{-a t }$	$\frac{2a}{a^2 + \omega^2}$	$a > 0$
4	$te^{-at}u(t)$	$\frac{1}{(a + j\omega)^2}$	$a > 0$
5	$t^n e^{-at}u(t)$	$\frac{n!}{(a + j\omega)^{n+1}}$	$a > 0$
6	$\delta(t)$	1	
7	1	$2\pi\delta(\omega)$	
8	$e^{j\omega_0 t}$	$2\pi\delta(\omega - \omega_0)$	
9	$\cos \omega_0 t$	$\pi[\delta(\omega - \omega_0) + \delta(\omega + \omega_0)]$	
10	$\sin \omega_0 t$	$j\pi[\delta(\omega + \omega_0) - \delta(\omega - \omega_0)]$	
11	$u(t)$	$\pi\delta(\omega) + \frac{1}{j\omega}$	
12	$\text{sgn } t$	$\frac{2}{j\omega}$	
13	$\cos \omega_0 t u(t)$	$\frac{\pi}{2}[\delta(\omega - \omega_0) + \delta(\omega + \omega_0)] + \frac{j\omega}{\omega_0^2 - \omega^2}$	
14	$\sin \omega_0 t u(t)$	$\frac{\pi}{2j}[\delta(\omega - \omega_0) - \delta(\omega + \omega_0)] + \frac{\omega_0}{\omega_0^2 - \omega^2}$	
15	$e^{-at} \sin \omega_0 t u(t)$	$\frac{\omega_0}{(a + j\omega)^2 + \omega_0^2}$	$a > 0$
16	$e^{-at} \cos \omega_0 t u(t)$	$\frac{a + j\omega}{(a + j\omega)^2 + \omega_0^2}$	$a > 0$
17	$\text{rect}\left(\frac{t}{\tau}\right)$	$\tau \text{sinc}\left(\frac{\omega\tau}{2}\right)$	
18	$\frac{W}{\pi} \text{sinc}(Wt)$	$\text{rect}\left(\frac{\omega}{2W}\right)$	
19	$\Delta\left(\frac{t}{\tau}\right)$	$\frac{\tau}{2} \text{sinc}^2\left(\frac{\omega\tau}{4}\right)$	
20	$\frac{W}{2\pi} \text{sinc}^2\left(\frac{Wt}{2}\right)$	$\Delta\left(\frac{\omega}{2W}\right)$	
21	$\sum_{n=-\infty}^{\infty} \delta(t - nT)$	$\omega_0 \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_0)$	$\omega_0 = \frac{2\pi}{T}$
22	$e^{-t^2/2\sigma^2}$	$\sigma\sqrt{2\pi}e^{-\sigma^2\omega^2/2}$	

Figure 3: Table of Common Fourier Transforms

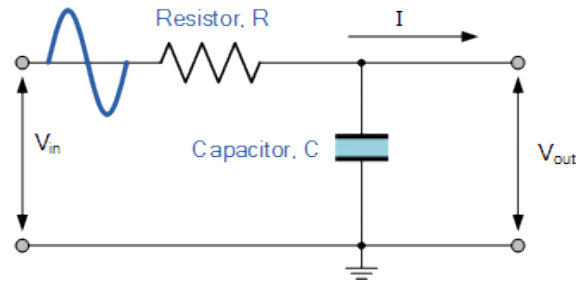
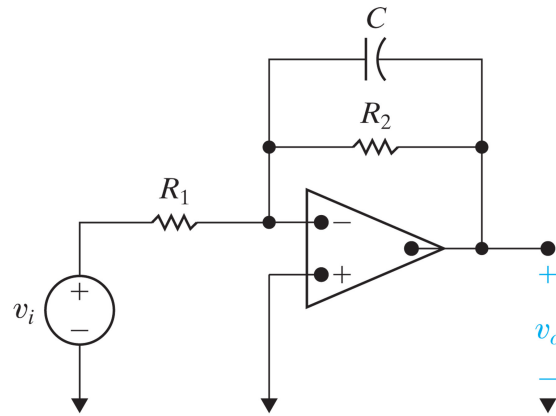
Figure 4: Passive Low Pass Filter ($f_c = \frac{1}{2\pi RC}$)

Figure 5: First Order Active Low Pass Filter

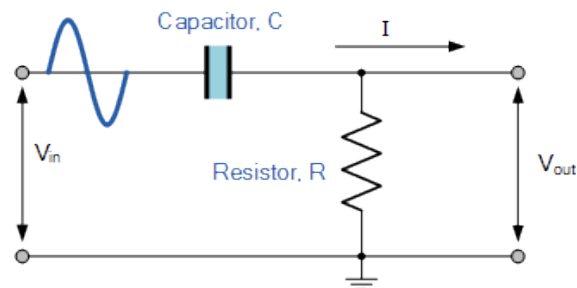
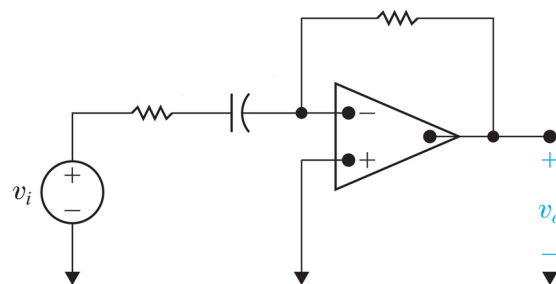
Figure 6: Passive High Pass Filter ($f_c = \frac{1}{2\pi RC}$)

Figure 7: First Order Active High Pass Filter