

# BASIC ELECTRONIC CIRCUITS

OP-AMP Applications: Active  
filters

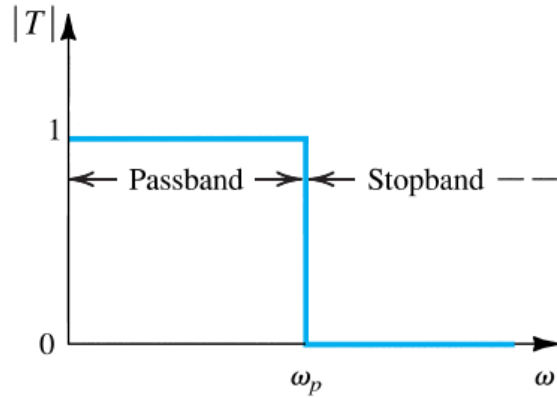
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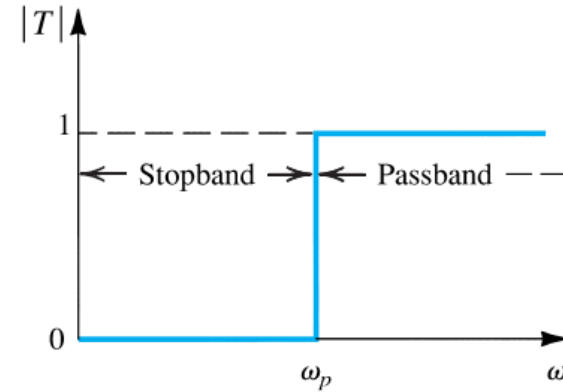
# Filters

- Pass band: A frequency band over which the magnitude of transmission is unity
- Stop band: A frequency band over which the magnitude of the transmission is zero.
- Major filter types are: Low pass, High pass, Band pass and Band reject

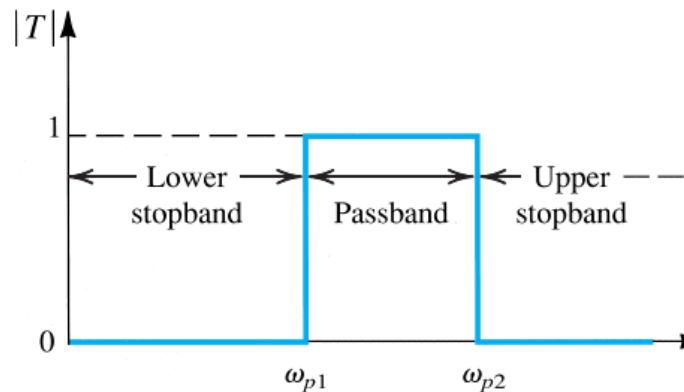
# Brick-wall responses of the filter types



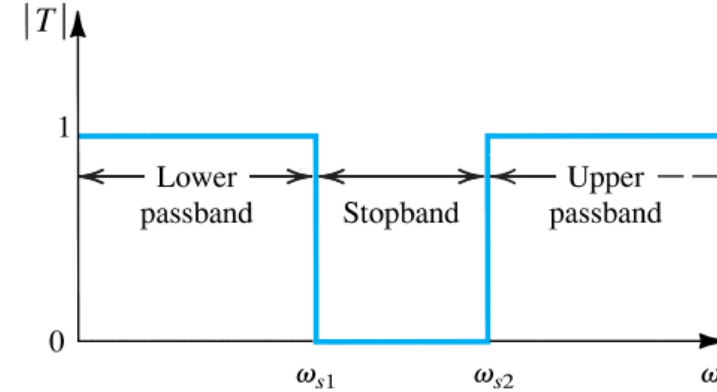
(a) Low-pass (LP)



(b) High-pass (HP)



(c) Bandpass (BP)



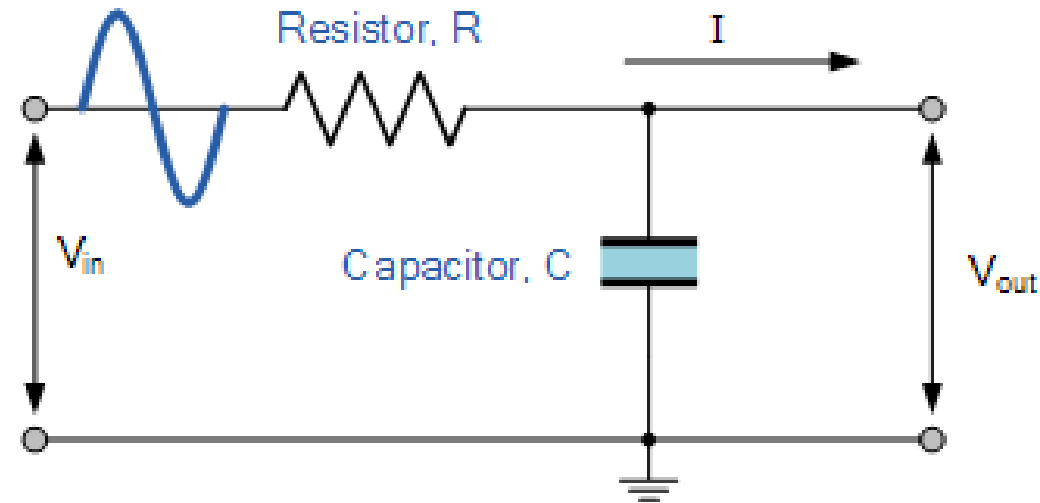
(d) Bandstop (BS)

# Passive Vs Active filters

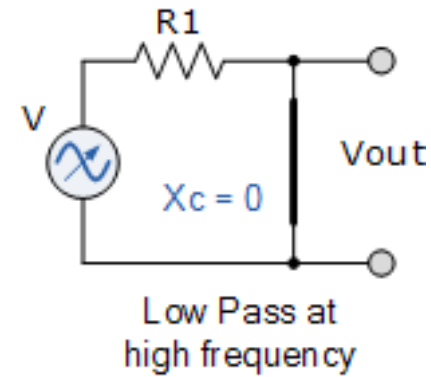
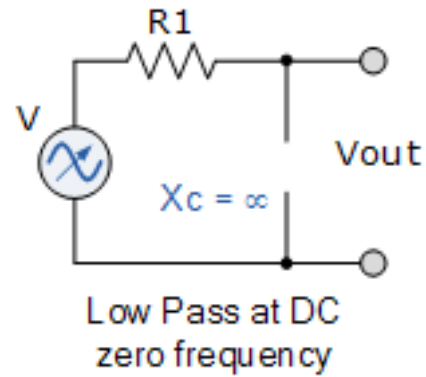
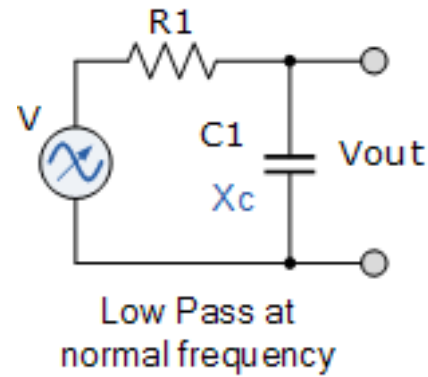
- **Passive filters** are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.
- **Active filters** contain amplifying devices to increase signal strength while passive do not contain amplifying devices to strengthen the signal

# RC Low Pass Filter: Passive

- A Low Pass Filter is a circuit that can be designed to modify, reshape or reject all unwanted high frequencies of an electrical signal and accept or pass only those signals wanted by the circuits designer.



$$V_{out} = V_{in} \times \frac{X_C}{\sqrt{R^2 + X_C^2}} = V_{in} \frac{X_C}{Z}$$

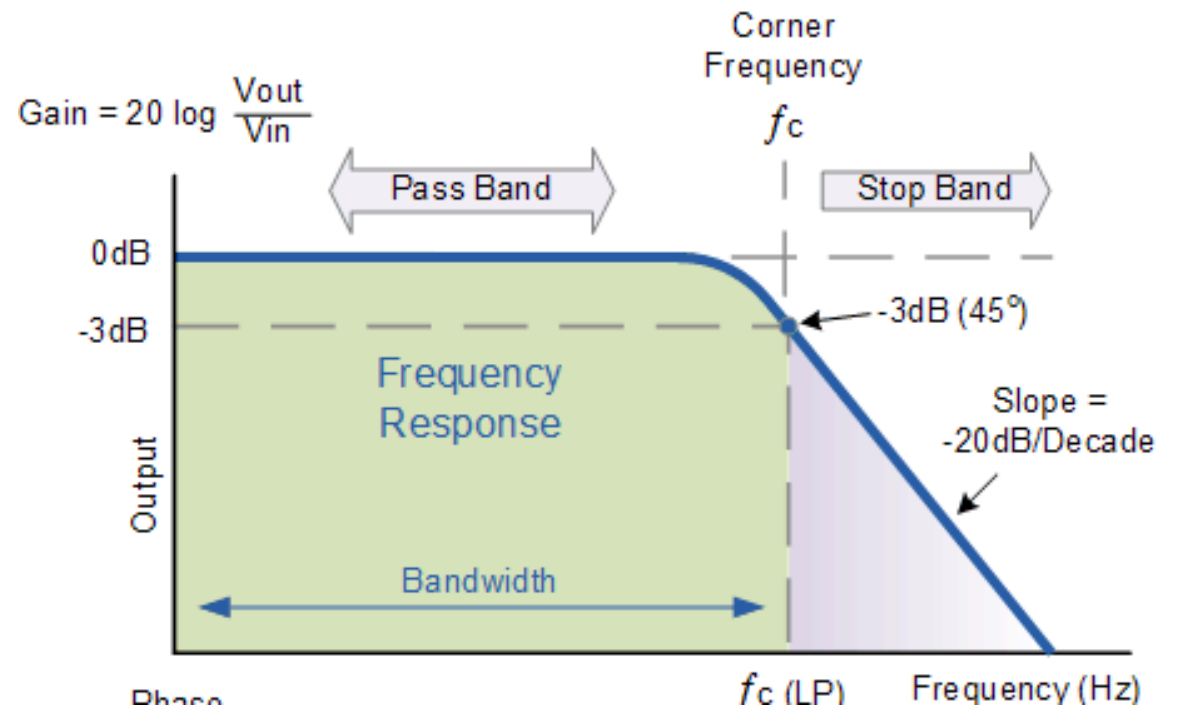


- $X_c$  - capacitive reactance, varies with applied frequency
- $X_c = 1/2\pi fC$
- Ex: A Low Pass Filter circuit consisting of a resistor of  $4.7k\Omega$  in series with a capacitor of  $47nF$  is connected across a  $10v$  sinusoidal supply. Calculate the output voltage ( $V_{OUT}$ ) at a frequency of  $100Hz$  and again at frequency of  $10kHz$ .

# Frequency Response:

- This "Cut-off", "Corner" or "Breakpoint" frequency is defined as being the frequency point where the capacitive reactance and resistance are equal,  $R = X_c$ .

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 4700 \times 47 \times 10^{-9}} = 720\text{Hz}$$





# Low Pass Active Filter

- Non inverting configuration

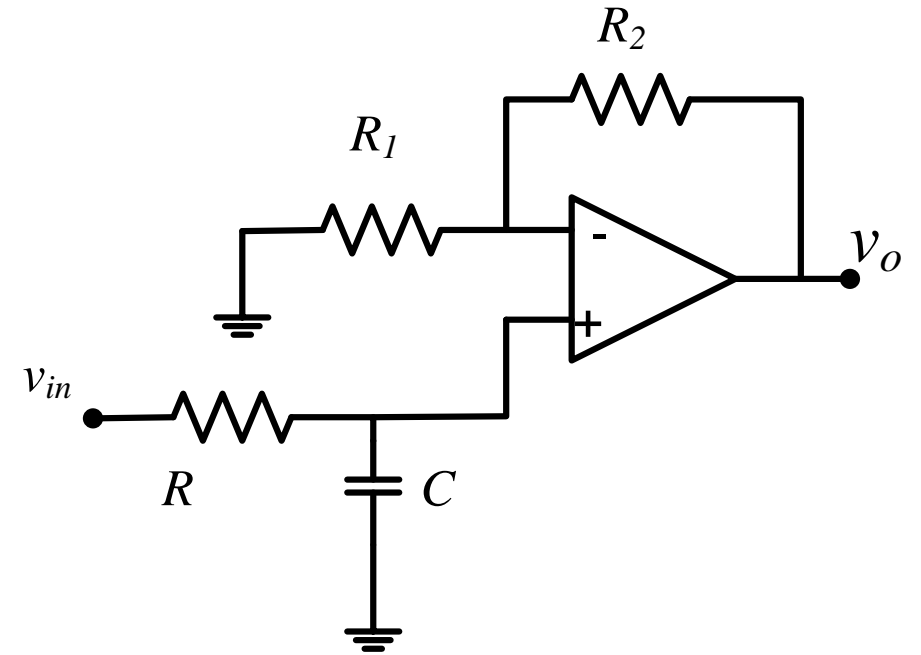
- Pass band gain 'G'  $G = \left(1 + \frac{R_2}{R_1}\right)$

- At low freq.  $f < f_c$ :  $v_o \cong G v_{in}$

- At the cut-off freq.  $f = f_c$ :  $v_o \cong \frac{G}{\sqrt{2}} v_{in}$

- At high freq.  $f > f_c$ :  $v_o < G v_{in}$

$$f_c = \frac{1}{2\pi RC}$$

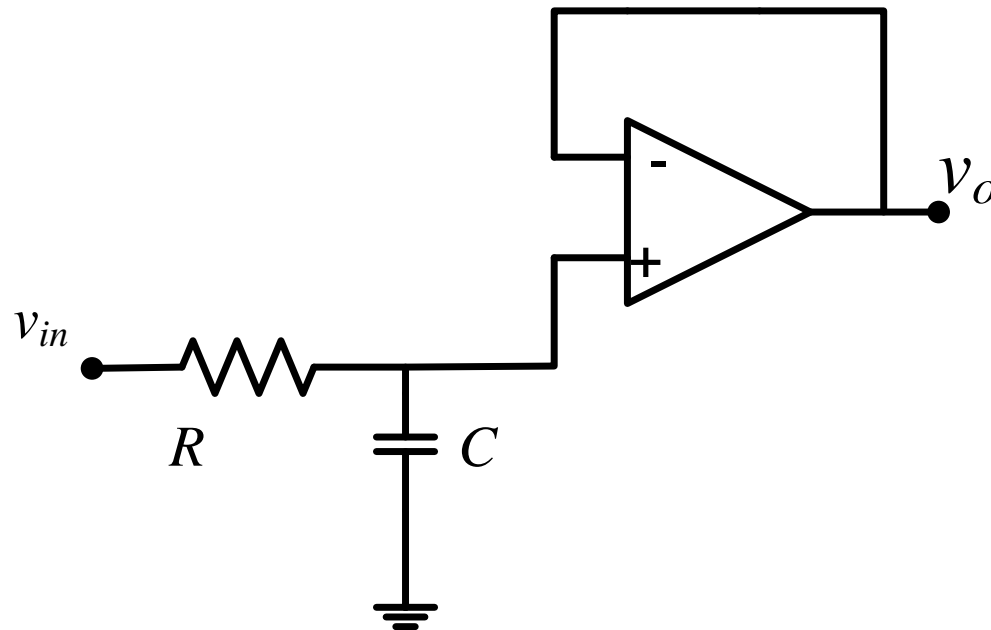


$$v_o = \frac{\left(1 + \frac{R_2}{R_1}\right)}{\sqrt{1 + \left(\frac{f}{f_c}\right)^2}} v_{in}$$

$$\text{DC Gain} = \left(1 + \frac{R_2}{R_1}\right)$$

# Low Pass Active Filter:

- Unit gain (Voltage follower)

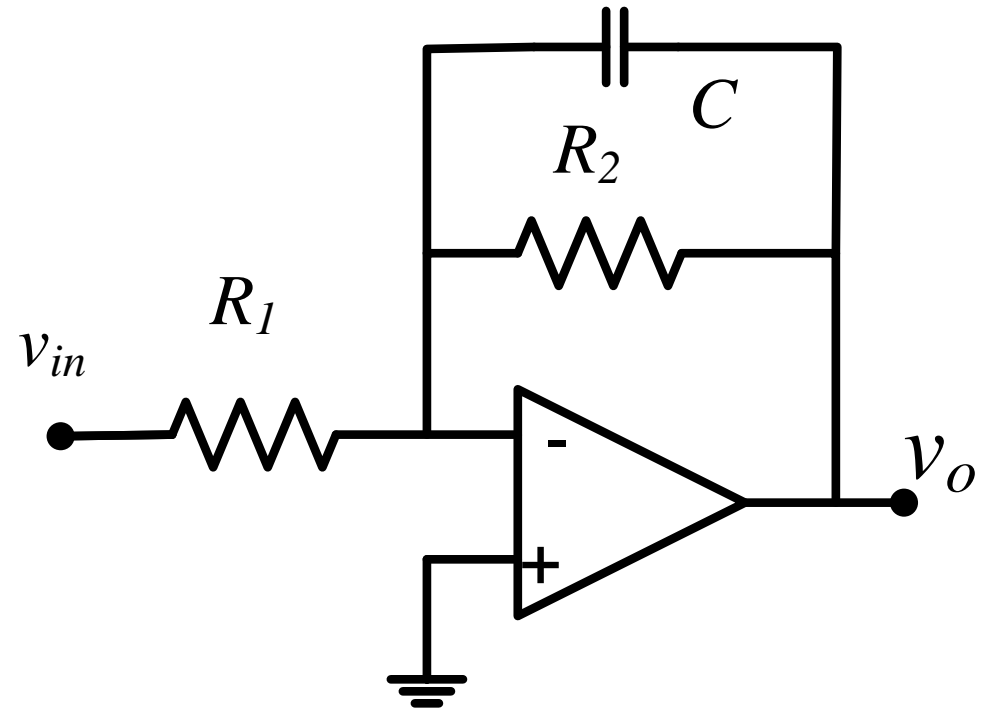


# Example:

- Design a non-inverting active low pass filter circuit that has a gain of ten at low frequencies, a high frequency cut-off or corner frequency of 159Hz and an input impedance of  $10\text{K}\Omega$ . Assume that the resistance in feed-in path is  $1\text{K}\Omega$ . Determine the voltage gain at 100 Hz, 10kHz.
- Ans:  $R_2 = 9\text{K}\Omega$ ;  $C = 100\text{ nF}$

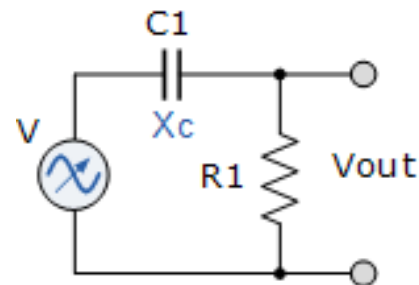
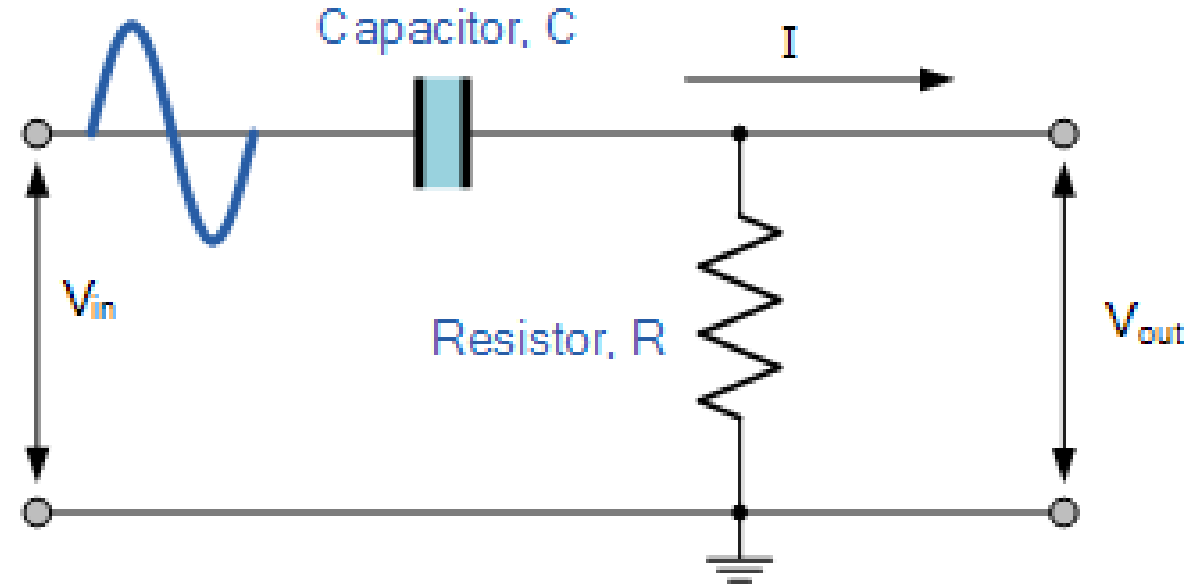
# Low Pass Active Filter: Inverting configuration

- DC gain =  $-R_2/R_1$
- Integrator (in time domain)

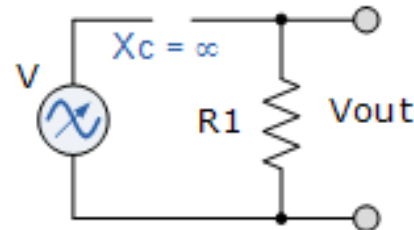


# High pass filter

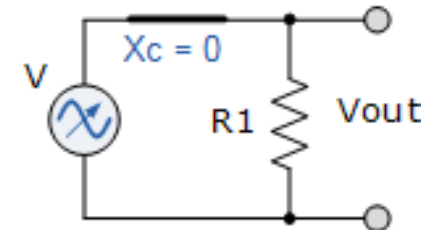
- A High Pass Filter is the exact opposite to the low pass filter circuit as the two components have been interchanged with the filters output signal now being taken from across the resistor.



High Pass at  
normal frequency



High Pass at DC  
zero frequency

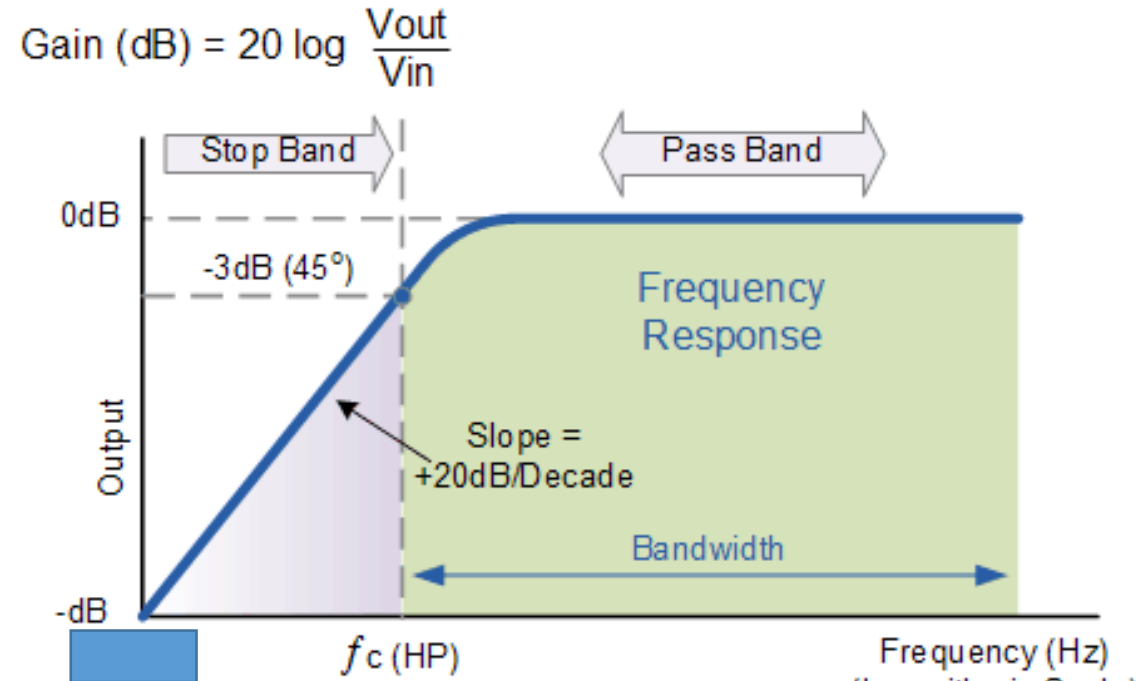


High Pass at  
high frequency

# Frequency Response:

$$f_c = \frac{1}{2\pi RC}$$

- Calculate the cut-off or "breakpoint" frequency ( $f_c$ ) for a simple passive high pass filter consisting of an 82pF capacitor connected in series with a 240k $\Omega$  resistor.



$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{R}{\sqrt{R^2 + X_c^2}} = \frac{R}{Z}$$

at low  $f$ :  $X_c \rightarrow \infty$ ,  $V_{out} = 0$   
at high  $f$ :  $X_c \rightarrow 0$ ,  $V_{out} = V_{in}$

# Active High Pass Filter

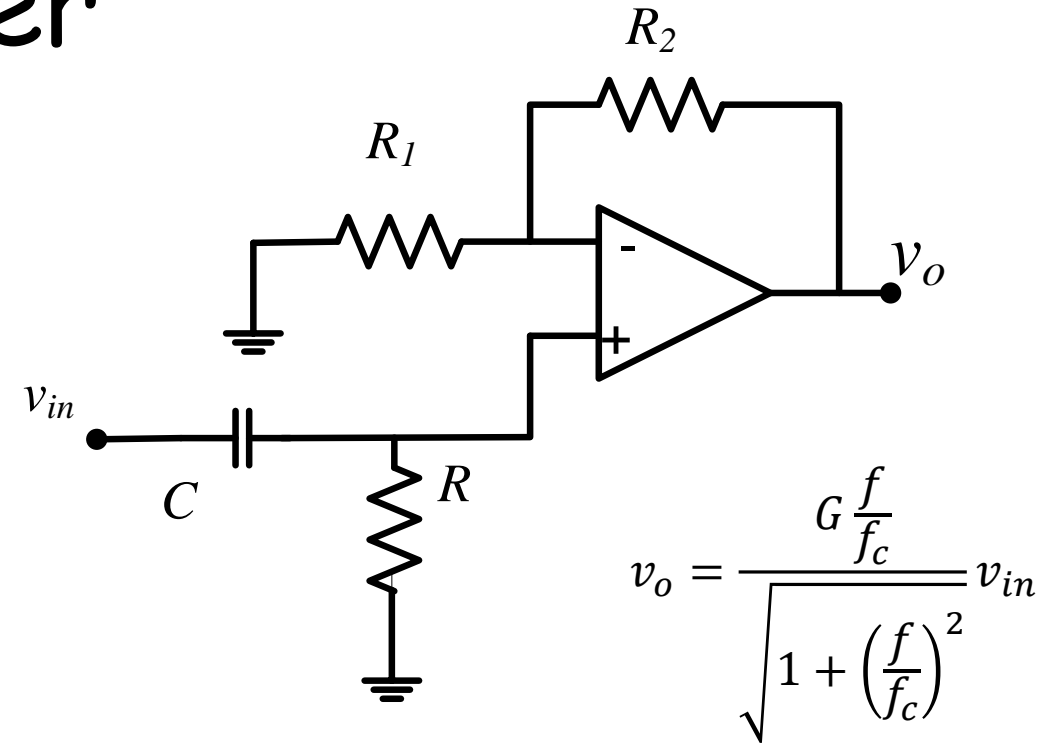
- Noninverting configuration

- Pass band gain  $G = \left(1 + \frac{R_2}{R_1}\right)$

- At low freq.  $f < f_c$ :  $v_o < Gv_{in}$

- At the cut-off freq.  $f = f_c$ :  $v_o \cong \frac{G}{\sqrt{2}} v_{in}$

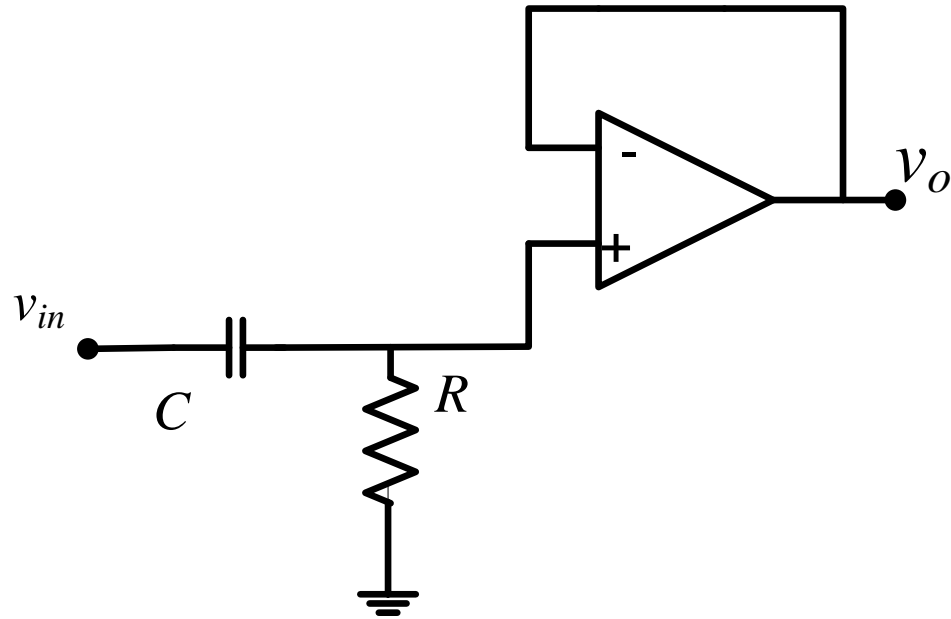
- At high freq.  $f > f_c$ :  $v_o \cong Gv_{in}$



$$f_c = \frac{1}{2\pi RC}$$

# High Pass Active Filter

- Unit gain



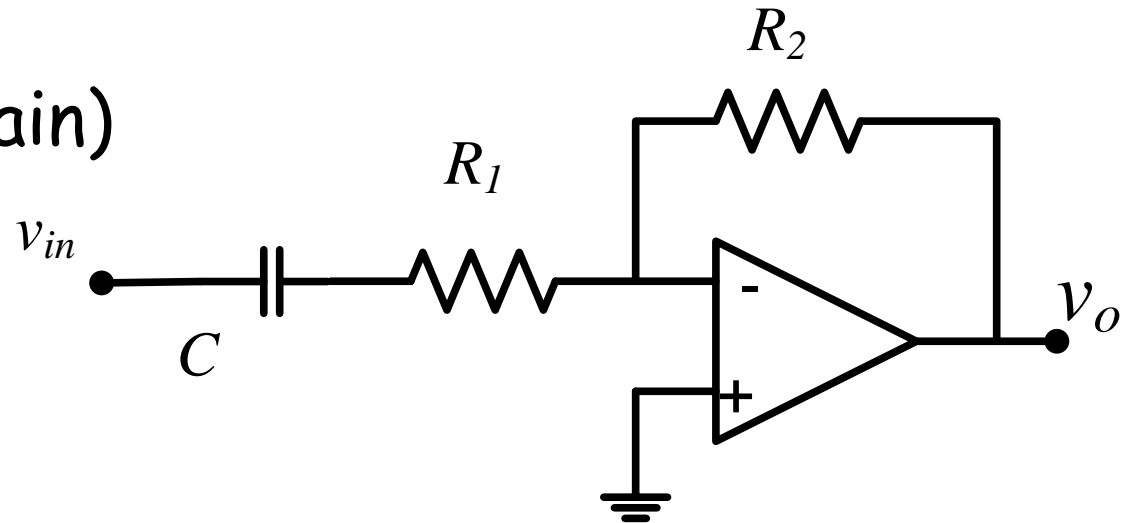


# Example:

- A first order active high pass filter has a pass band gain of two and a cut-off corner frequency of 1kHz. If the input capacitor has a value of 10nF, calculate the value of the cut-off frequency determining resistor and if the feed in resistor is 10 K $\Omega$  determine feedback resistance.
- Also determine the gain at 10 Hz, 100 Hz, 1KHz and 10 kHz.

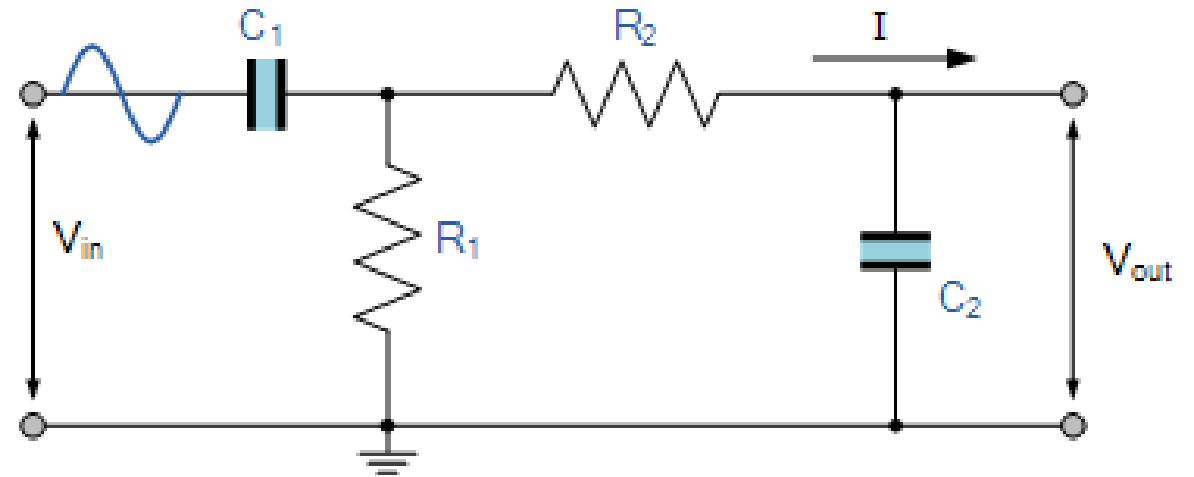
# High Pass Active Filter

- Inverting configuration
- Differentiator (time domain)



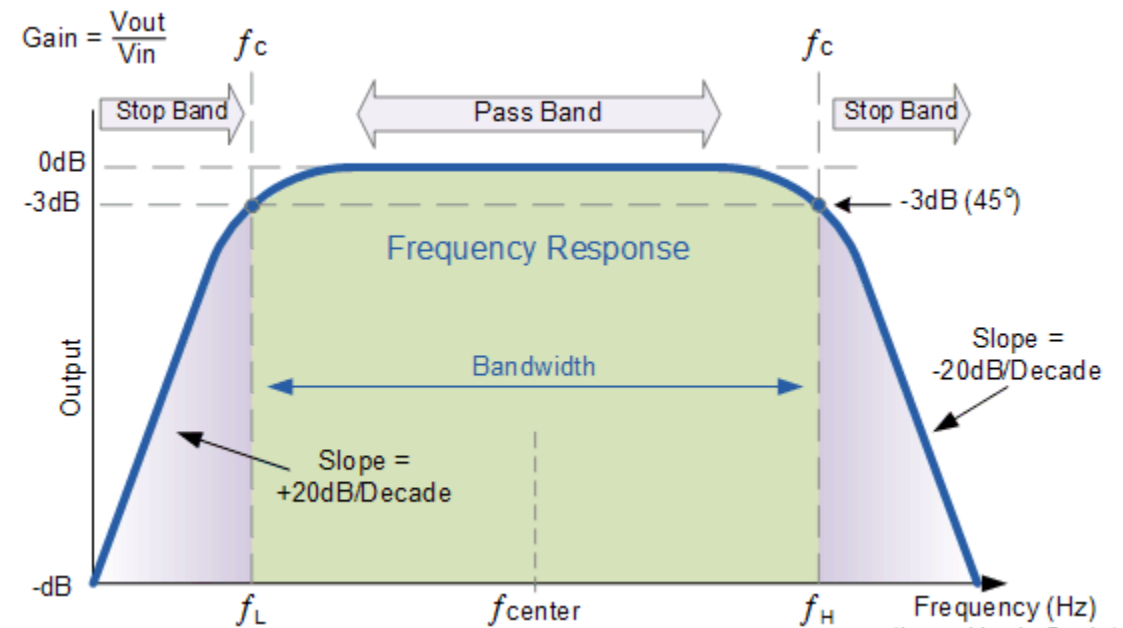
# Band pass filter

- Passive Band Pass Filters can be made by connecting together a low pass filter with a high pass filter



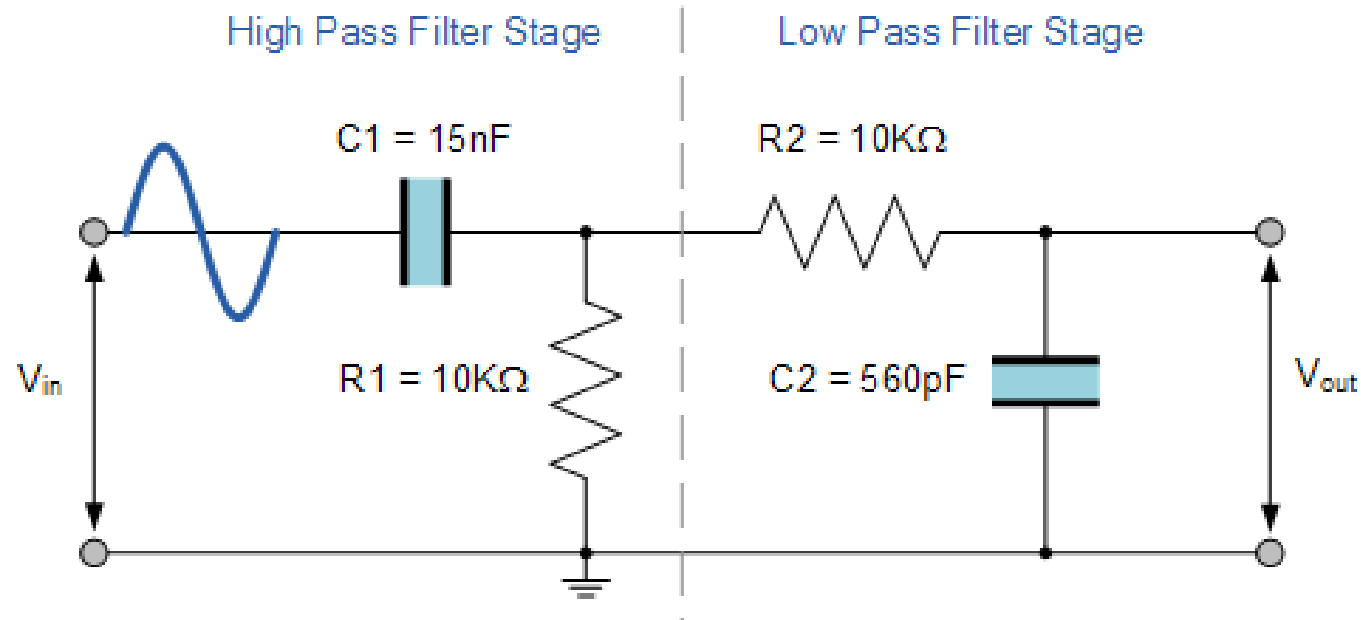
# Frequency Response:

- $f_L$  – cut off frequency of the high pass stage
- $f_H$  – cutoff frequency of the low pass stage
- Bandwidth =  $f_H - f_L$ .



$$f_r = \sqrt{f_L \times f_H}$$

- Ex: A second-order band pass filter is to be constructed using RC components that will only allow a range of frequencies to pass above 1kHz (1,000Hz) and below 30kHz (30,000Hz). Assuming that both the resistors have values of  $10\text{k}\Omega$ , calculate the values of the two capacitors required.



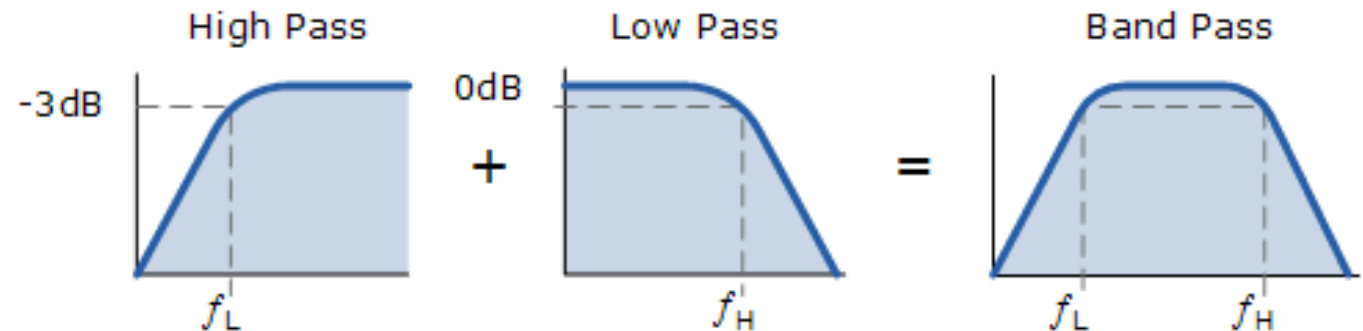
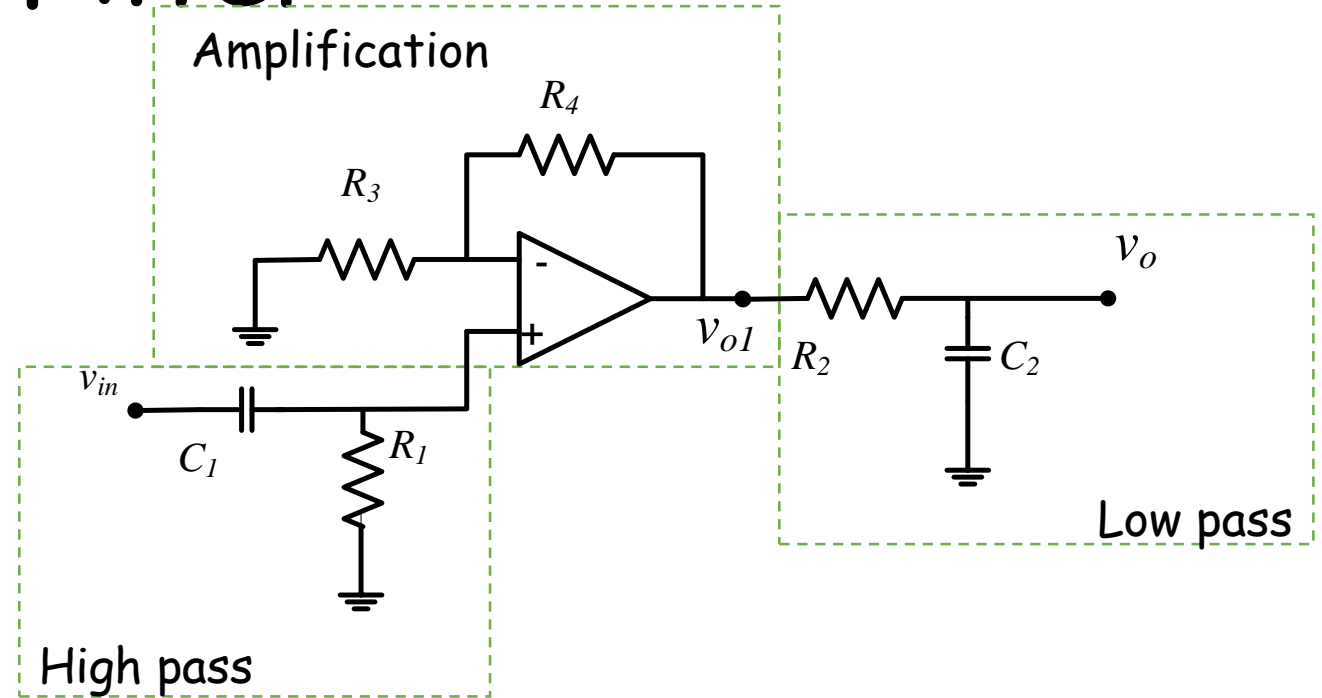
# Band pass Active Filter

- Non inverting configuration

$$v_o = \frac{\left(1 + \frac{R_4}{R_3}\right)}{\sqrt{1 + \left(\frac{f}{f_H}\right)^2}} \frac{f}{f_L} v_{in}$$

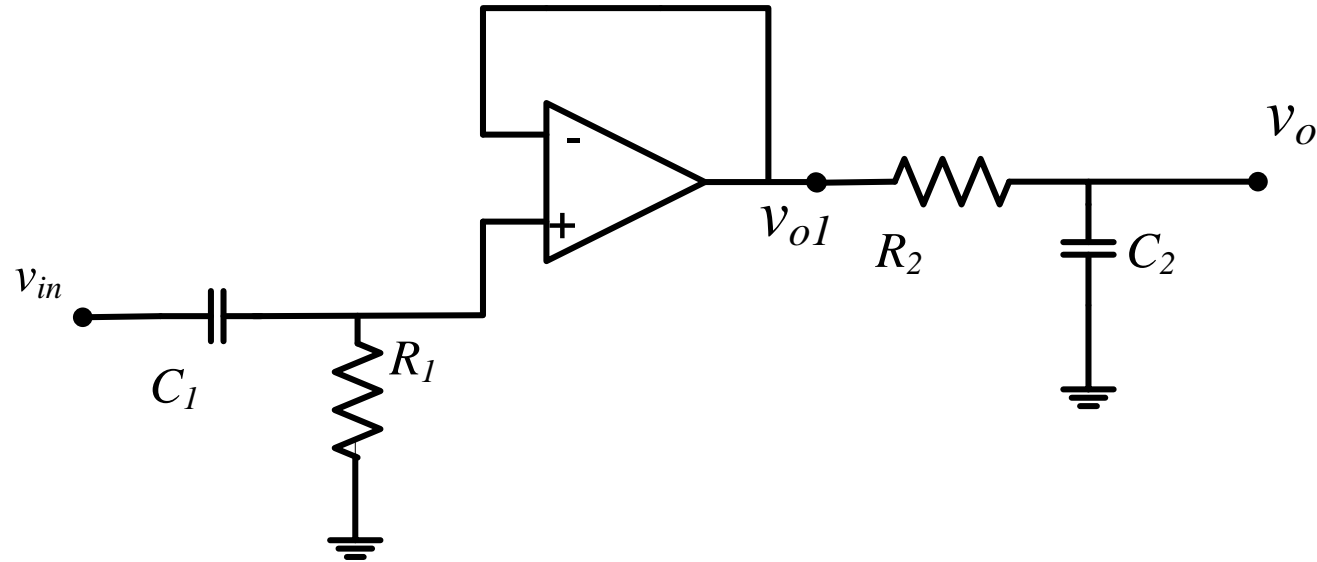
$$f_L = \frac{1}{2\pi R_1 C_1} \quad f_H = \frac{1}{2\pi R_2 C_2}$$

$$f_r = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}$$



# Band pass active filter

- Unit Gain (Voltage follower)



# Band Pass Active Filter

- Inverting Configuration

