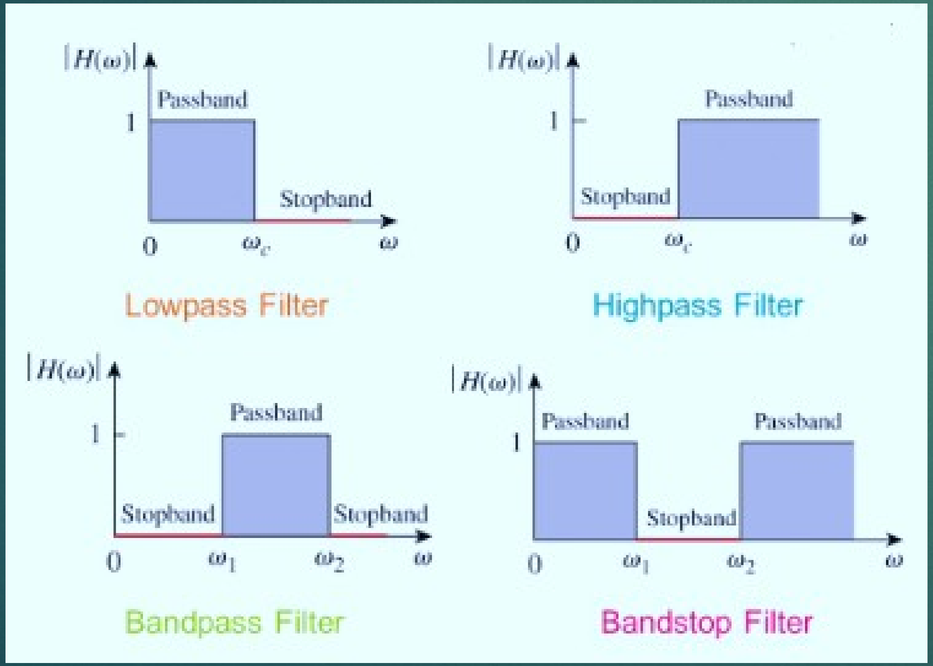
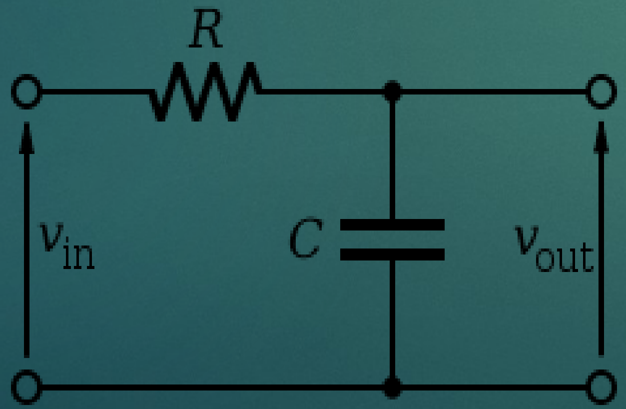
Active Filters

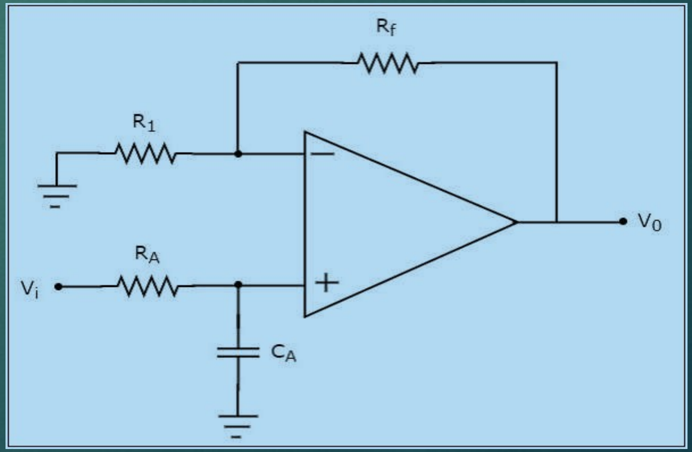


Filters

- A filter is a circuit capable of passing (or amplifying) certain frequency signals while attenuating other frequency signals.
- The filters are divided based on the components used while designing the filters.
- If the design of the filter is completely based on passive components then the filter is called passive filter.
- On the other hand, if we use an active component (op-amp, voltage source, current source) while designing a circuit then the filter is called an active filter.

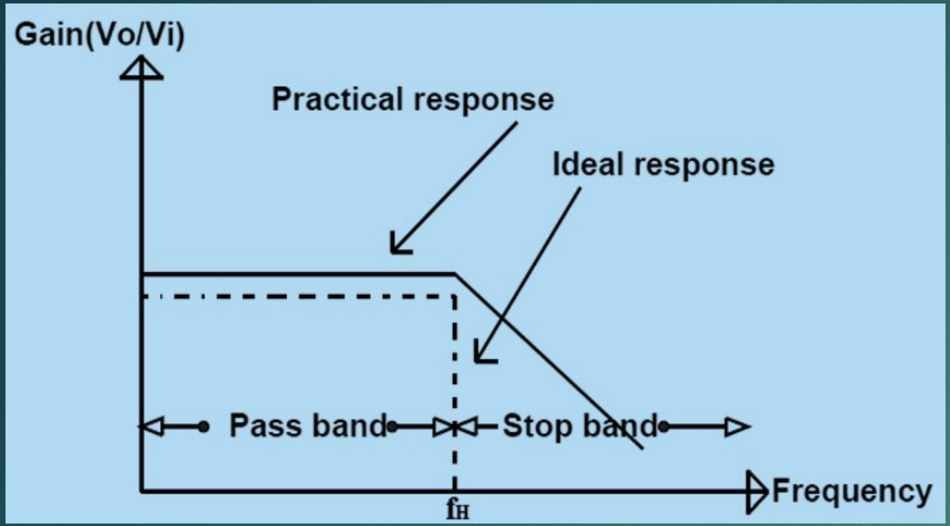


Passive Filter

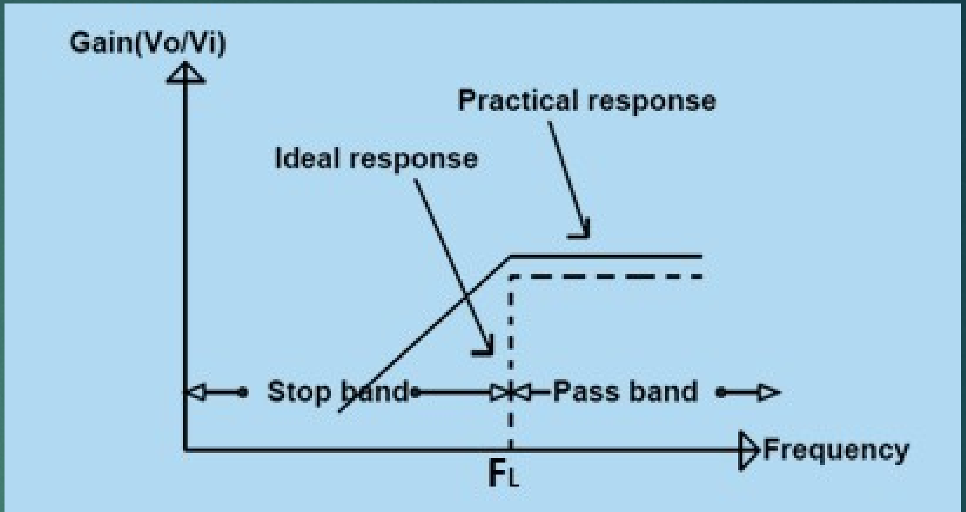


Active Filter

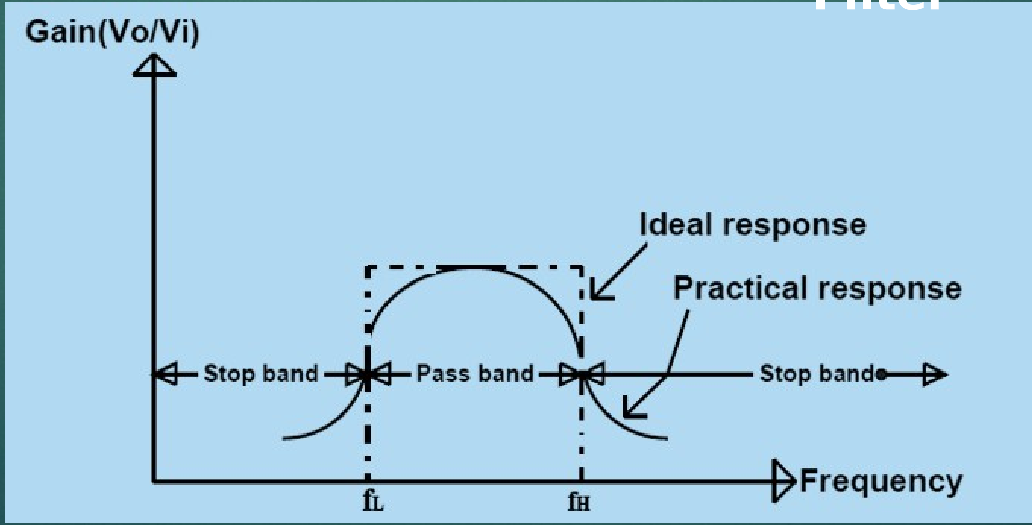
Filter Response



Low Pass Filter



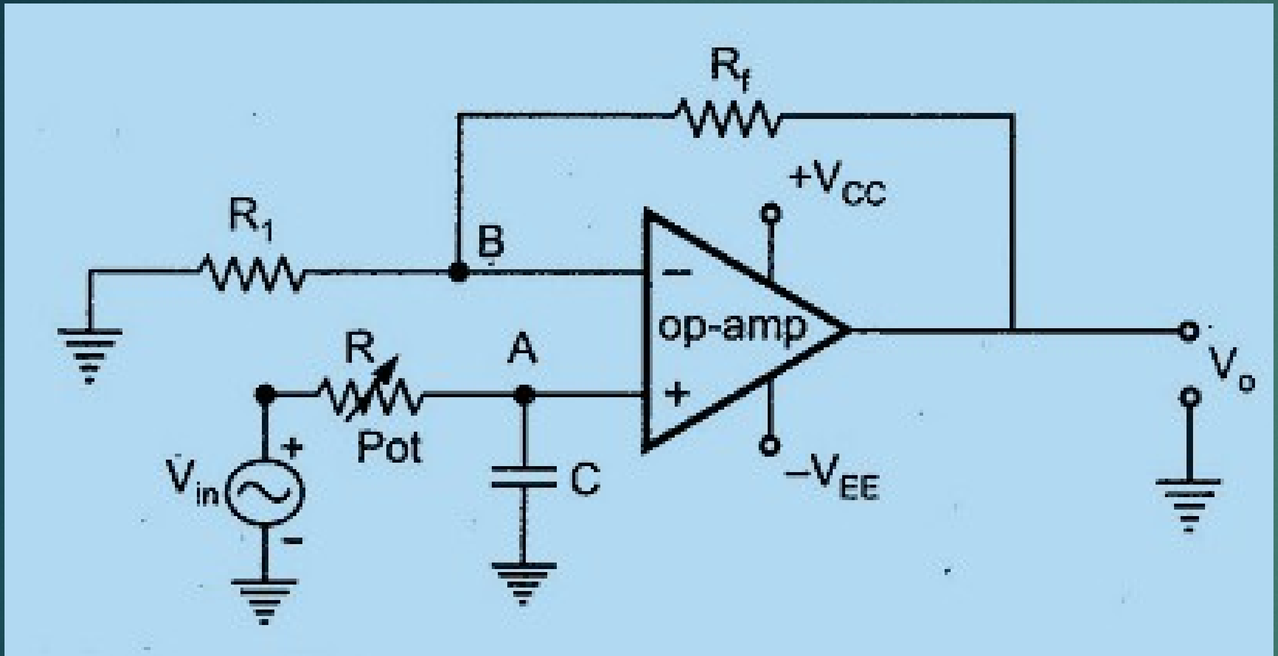
High Pass Filter

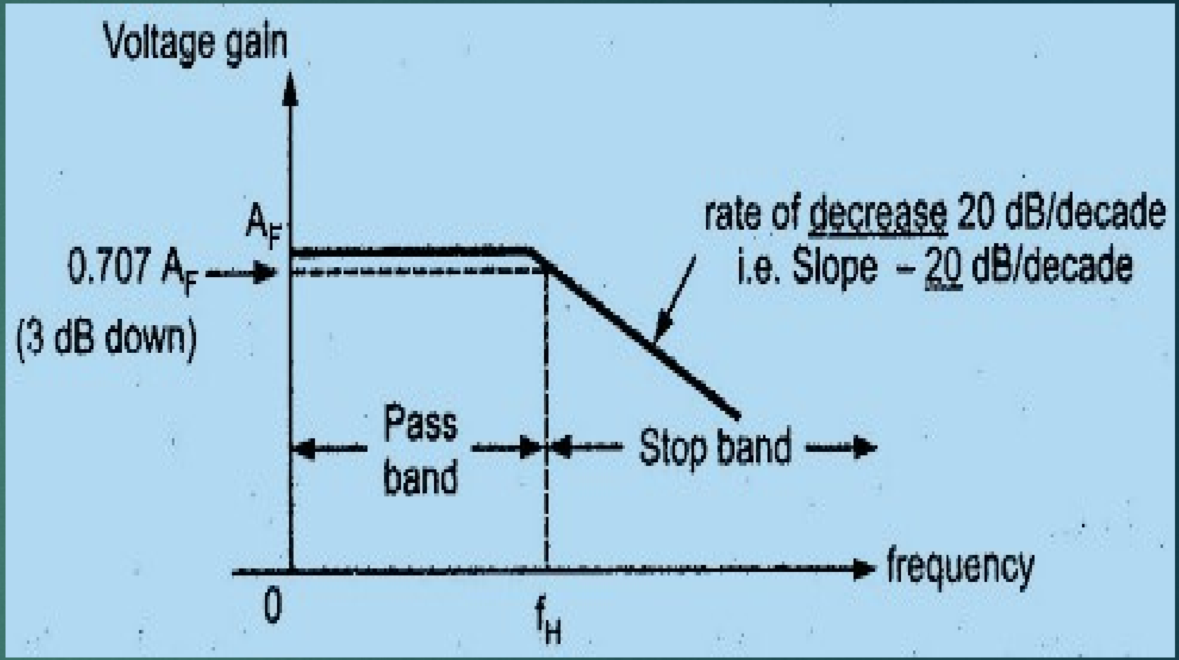


Band Pass Filter

First Order Low Pass Butterworth Filter

A low pass filter will pass low frequency signals while attenuating the high frequency signals.





The range of frequencies for which a filter does not cause significant attenuation is called the **passband**, and the range of frequencies for which the filter does cause significant attenuation is called the **stopband**.

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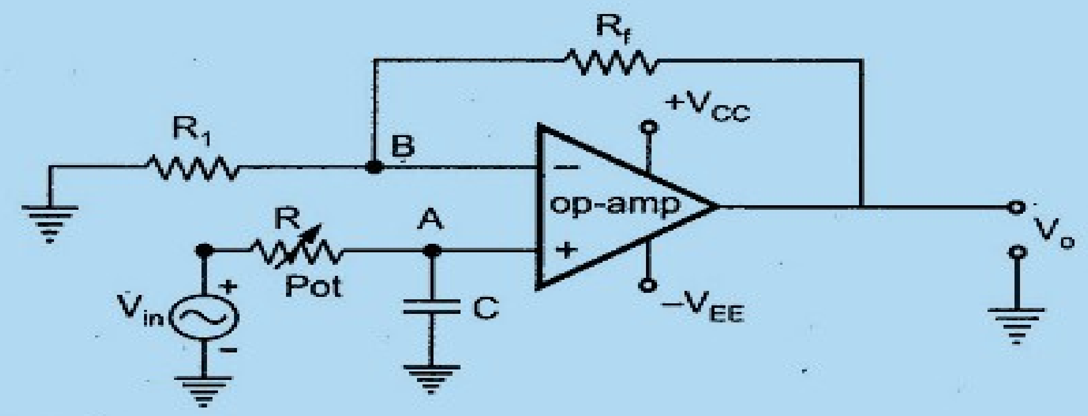


By potential divider rule, the voltage at the noninverting input terminal A which is the voltage across capacitor C is given by:

$$V_A = \frac{-jX_C}{R - jX_C} \cdot V_{in} \quad \ldots (1)$$

$$V_A = \frac{-j\left(\frac{1}{2\pi fC}\right)}{R - j\left(\frac{1}{2\pi fC}\right)} \cdot V_{in} = \frac{-j}{2\pi fRC - j} \cdot V_{in}$$

$$= \frac{V_{in}}{1 - \frac{2\pi fRC}{j}}$$

$$-j = \frac{1}{j} \quad \text{and} \quad -\frac{1}{j} = j$$

$$V_A = \frac{V_{in}}{1 + j2\pi fRC} \quad \ldots (2)$$

$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_A \quad \ldots (3)$$

$$V_o = \left(1 + \frac{R_f}{R_1}\right) \frac{V_{in}}{(1 + j2\pi fRC)}$$

$$\frac{V_o}{V_{in}} = \frac{A_F}{1 + j\left(\frac{f}{f_H}\right)} \quad (4)$$

$$A_F = \left(1 + \frac{R_f}{R_1}\right) = \text{gain of filter in pass band} \quad \ldots (5)$$

$$f_H = \frac{1}{2\pi RC} = \text{high cut off frequency of filter} \quad \ldots (6)$$

$$f = \text{operating frequency}$$

Continued

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_F}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

1. At very low frequencies, $f < f_H$

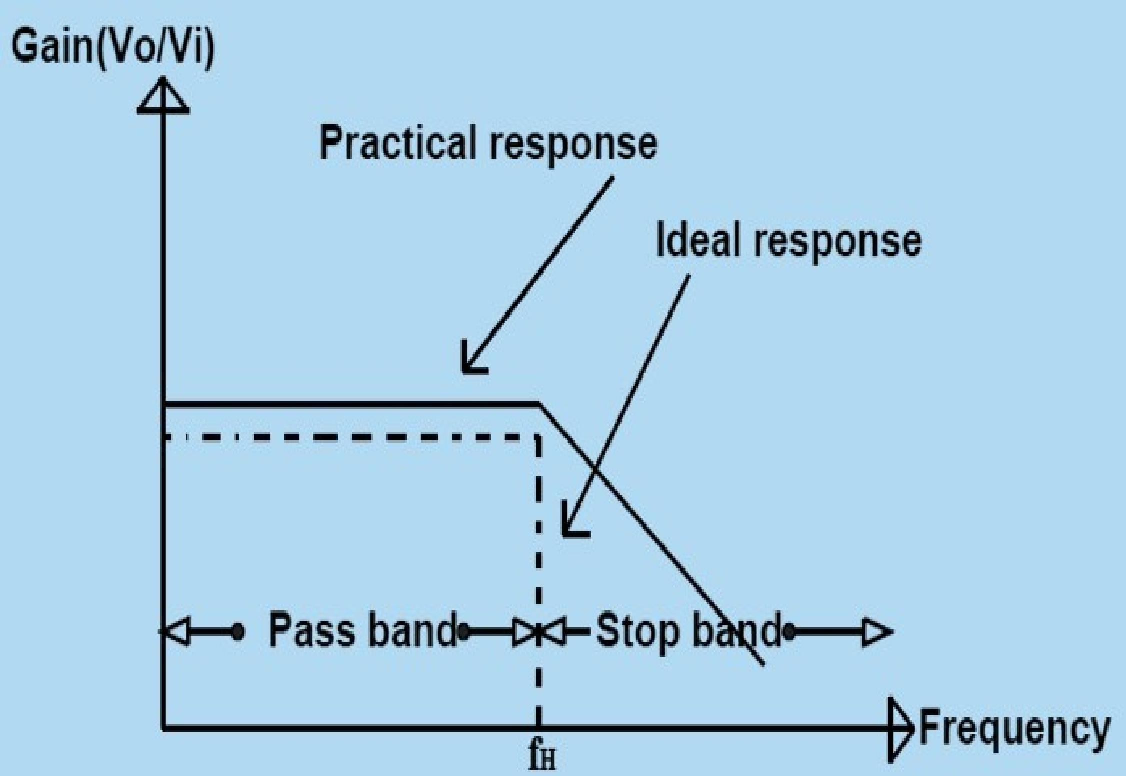
$$\left|\frac{V_o}{V_{in}}\right| \cong A_F \text{ i.e. constant}$$

2. At $f = f_H$,

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_F}{\sqrt{2}} = 0.707\,A_F \quad \text{i.e. 3 dB down to the level of } A_F.$$

3. At $f > f_H$

$$\left|\frac{V_o}{V_{in}}\right| < A_F$$



Filter Design Steps

Design Steps

The design steps for the first order low pass Butterworth filter are

1) Choose the cut off frequency, f_H.

2) Choose the capacitance C usually betwen 0.001 and 1 μF. Generally, it is selected as 1 μF or less than that. For better performance, mylar or tantalum capacitors are selected.

3) Now, for the RC circuit,

$$f_H = \frac{1}{2\pi R C}$$

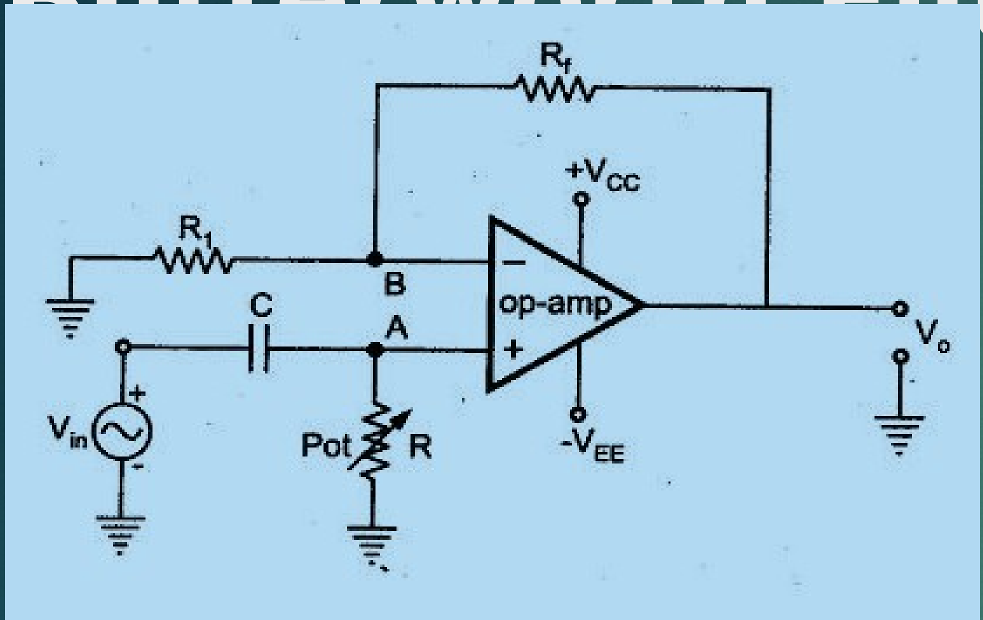
Hence, as f_H and C are known, calculate the value of R.

4) The resistances R_f and R_1 can be selected depending on the required gain in the pass band.

$$A_F = 1 + \frac{R_f}{R_1}$$

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 10KΩ.

First Order High Pass Butterworth Filter



A high pass filter that will pass the high frequency signals while attenuating the low frequency signals.

For the first order high pass filter, the output voltage is

$$V_o = \left(1 + \frac{R_F}{R_1}\right) \times \left(\frac{j2\pi f RC}{1 + j2\pi f RC}\right) \times V_{in}$$

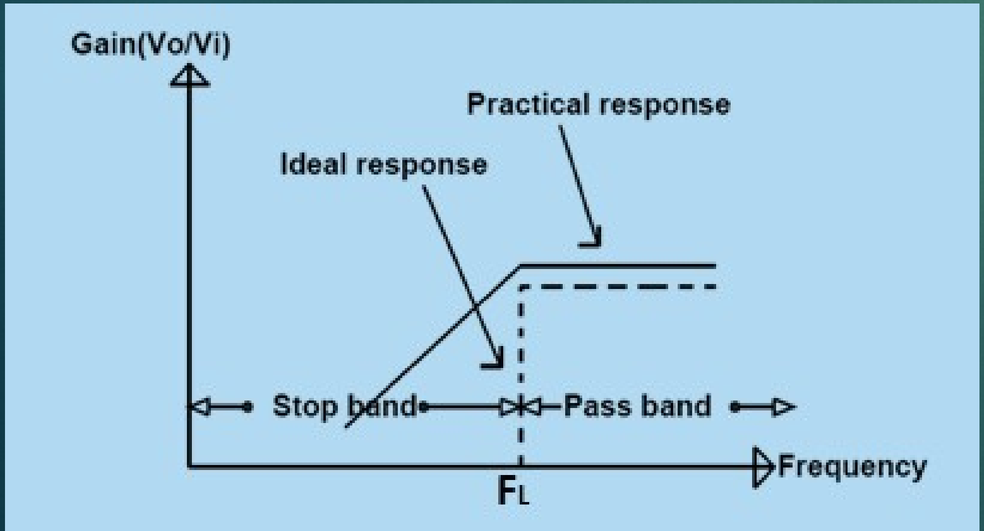
$$\frac{V_o}{V_{in}} = A_F \times \left(\frac{j(f/f_L)}{1 + j(f/f_L)}\right)$$

where

$A_F = 1 + R_F/R_1$ — pass band gain of the filter

f = frequency of the input signal

$f_L = 1/(2\pi RC)$ — low cutoff frequency

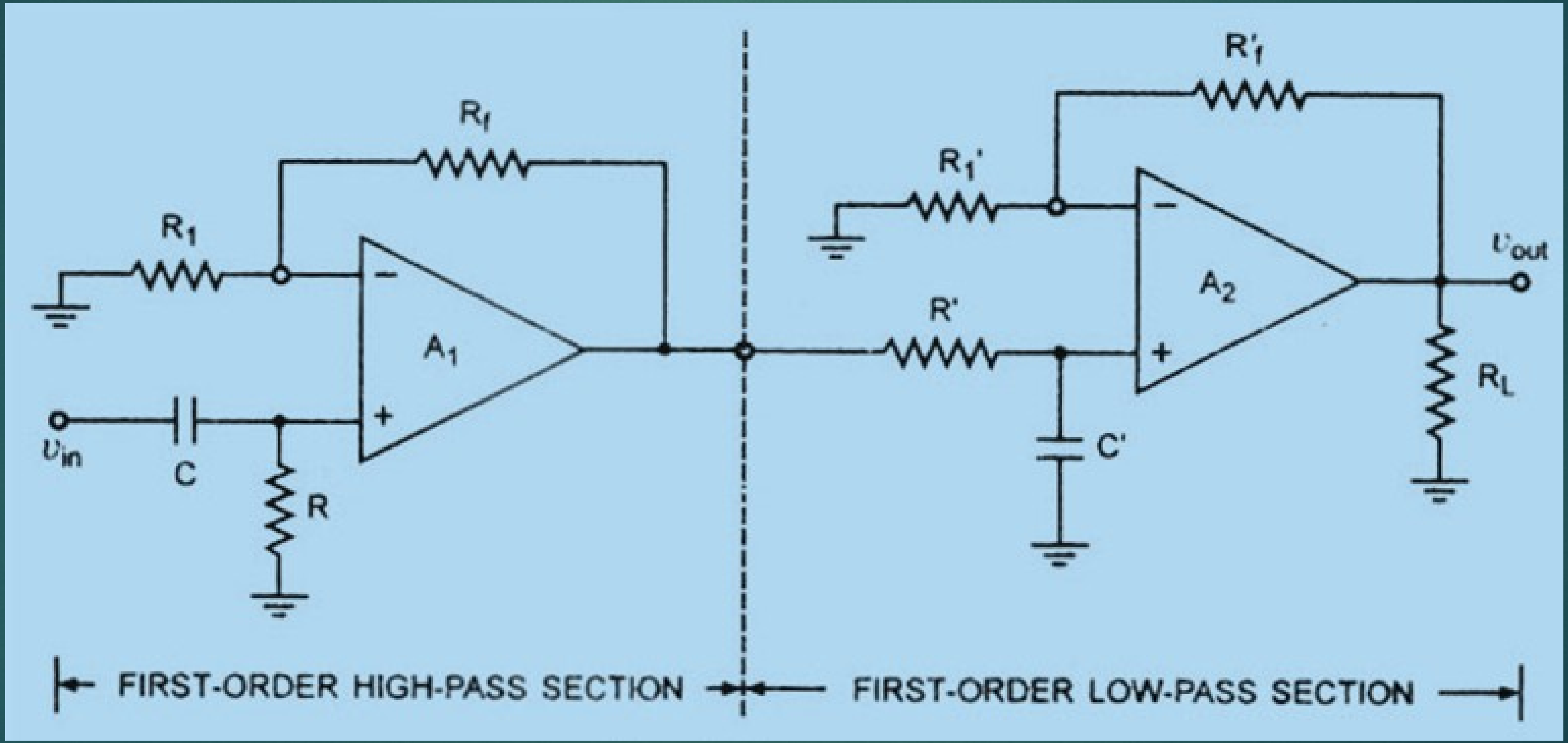


Hence the magnitude of the voltage gain is

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_F (f/f_L)}{\sqrt{1 + (f/f_L)^2}}$$

Band Pass Filter

- A band-pass filter is a circuit which is designed to pass signals only in a certain band of frequencies while attenuating all signals outside this band.



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- The parameters of importance in a bandpass filter are the high and low cut-off frequencies (f_H and f_L), the bandwidth (BW), the centre frequency f_c, centre-frequency gain, and the selectivity or Q.
- **There are basically two types of bandpass filters viz wide bandpass and narrow bandpass filter**s.
- A bandpass filter is defined as a wide bandpass if its figure of merit or quality factor Q is less than 10 while the bandpass **filters with Q > 10 are called the narrow bandpass filters.**
- Thus Q is a measure of selectivity, meaning the higher the value of Q the more selective is the filter, or the narrower is the bandwidth (BW).

$$Q = \frac{f_C}{\mathrm{BW}} = \frac{f_C}{f_H - f_L}$$

For the wide band-pass filter the center frequency f_C can be defined as

$$f_C = \sqrt{f_H f_L}$$

where f_H = high cutoff frequency (Hz)
f_L = low cutoff frequency of the wide band-pass filter (Hz)

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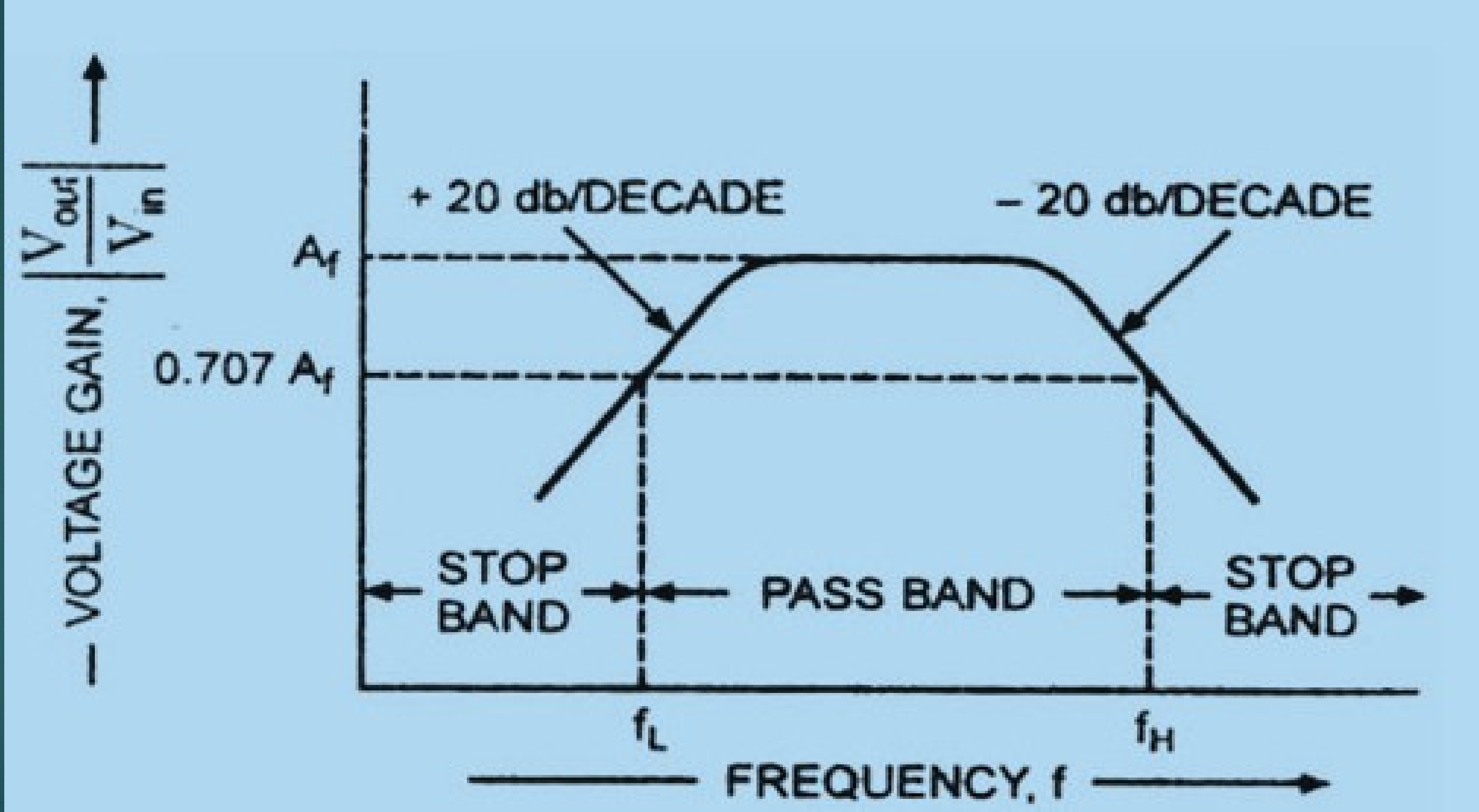

VOLTAGE GAIN, $\left|\frac{V_{out}}{V_{in}}\right|$
+ 20 db/DECADE
− 20 db/DECADE
A_f
0.707 A_f
STOP BAND
PASS BAND
STOP BAND
f_L
f_H
FREQUENCY, f

Thank you