## BAND PASS FILTERS

A bandpass filter is basically a frequency selector. It allows one particular band of frequencies to pass. Thus, the pass band is between the two cut-off frequencies $f_H$ and $f_L$ where $f_H > f_L$. Any frequency outside this band gets attenuated. The frequency response of band pass filter is shown in Fig. 3.10.1.

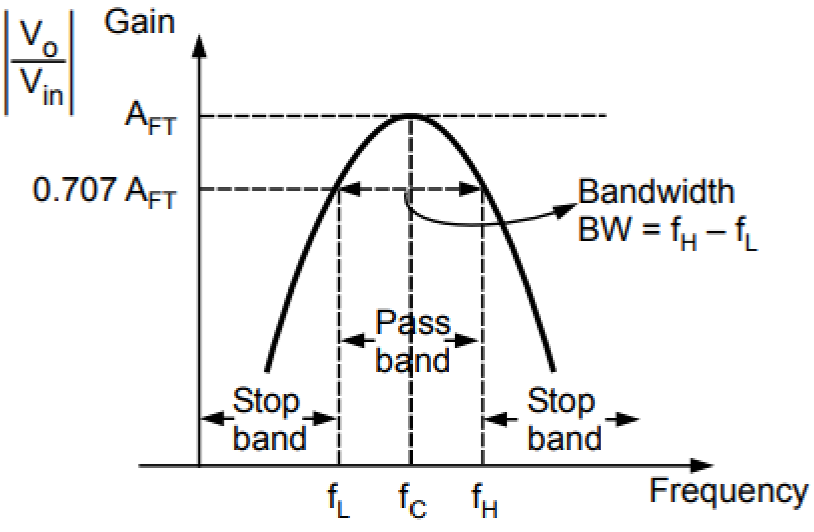



Fig. 3.10.1 Bandpass filter

The pass band which is between $f_H$ and $f_L$ is called bandwidth of the filter denoted as BW.

$BW = f_H - f_L$ ….. (3.10.1)

The frequency at the centre of the pass band is called centre frequency denoted as $f_C$.

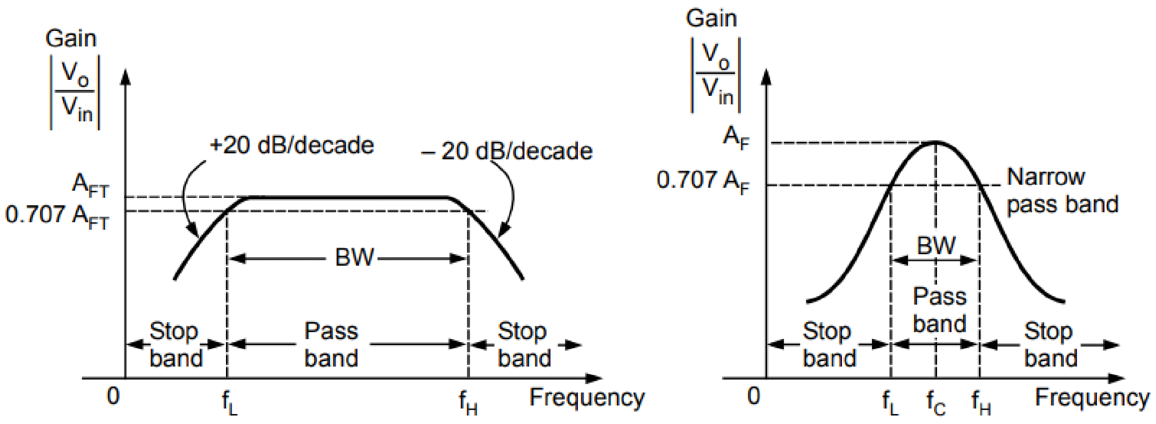
The gain is maximum at $f_C$ and is denoted as $A_{FT}$ called total passband gain.

Practically, the $f_C$ is not exactly at the centre of the pass band hence, it is also called as resonant frequency. The gain at $f_L$ and $f_H$ is 0.707 $A_{FT}$.

There are two types of bandpass filters which are classified based on the figure of merit or quality factor (Q).

i) For $Q < 10$, the bandpass filter is called wide bandpass filter. In this type, the bandpass is wide and we get large bandwidth. The response is shown in the Fig. 3.10.2 (a).

ii) For $Q > 10$, the bandpass filter is called narrow bandpass filter. The bandpass is very narrow and the bandwidth is very small. Higher the value of Q, narrower is the passband and more selective is the filter. In the narrow band filter, the gain peaks at the centre frequency. The response is shown in Fig. 3.10.2 (b).




(a) Wide band pass filter

Fig. 3.10.2

(b) Narrow band pass filter

The gain roll off for $f < f_L$ is + 20 dB/decade while $f > f_H$ it is - 20 dB/decade.

For wide band pass filter, the centre frequency is given by,

$f_C = \sqrt{f_L \, f_H}$ … (3.10.2)

The relationship between Q and 3 dB bandwidth with fc is given by,

$Q = f_C / B_W = F_C / f_H - f_L$ … (3.10.3)

## 1. Wide Band Pass Filter

The wide band pass filter can be realised by simply cascading a high pass filter and low pass filter. If both high pass and low pass filters are of first order, the gain roll off in both the stop bands are ± 20 dB/decade and wide band pass filter is of first order. To get gain roll off ± 40 dB/decade and second order wide band pass filter, both high pass and low pass filters must be of second order and so on.

The Fig. 3.10.3 shows the first order wide band pass filter obtained by cascading first order high pass and low pass filter sections.

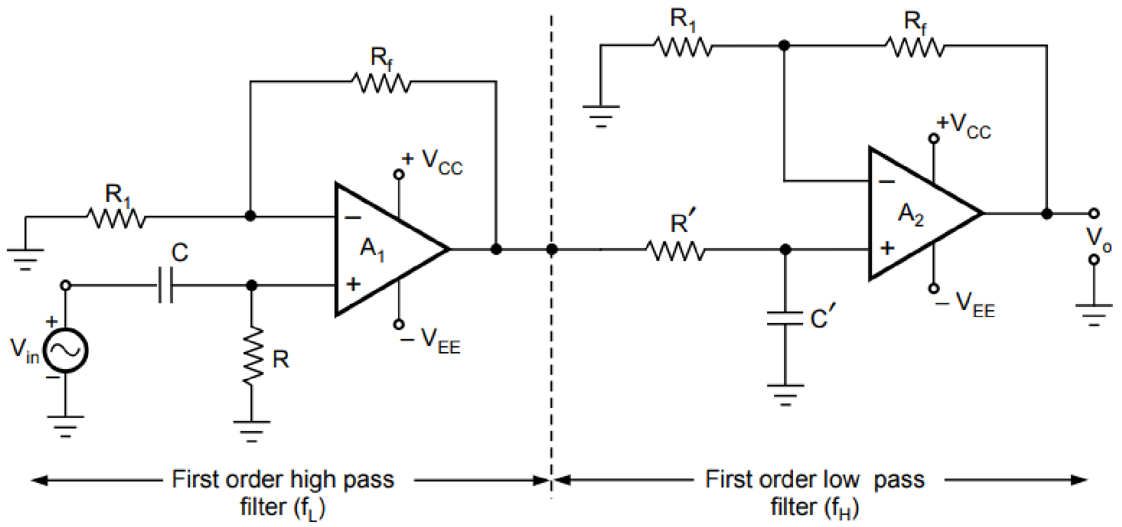



**Fig. 3.10.3 Wide band pass filter**

For wide band pass response, $f_H$ must be greater than $f_L$. The voltage gain expressions for the two sections are reproduced here for the convenience.

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

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_F\left(\frac{f}{f_L}\right)}{\sqrt{1+\left(\frac{f}{f_L}\right)^2}} \quad \text{High pass section}$$

The design steps discussed earlier for first order low pass and high pass filters, are to be used to design the wide band pass filter of first order.

As the two circuits are in cascade, the overall gain of wide band pass filter is the product of the two gains expressed as,

$$\left|\frac{V_o}{V_{in}}\right| = \frac{A_{FT}\left(\frac{f}{f_L}\right)}{\sqrt{\left[1+\left(\frac{f}{f_L}\right)^2\right]\left[1+\left(\frac{f}{f_H}\right)^2\right]}} \quad \ldots (3.10.4)$$

where $A_{FT}$ = Total pass band gain

f = Input frequency in Hz

$f_L$ = Lower cut off frequency in Hz

$f_H$ = Higher cut-off frequency in Hz

and $A_{FT} = A_1 A_2$ …. (3.10.5)

where

$A_1$ = Gain of high pass section

$A_2$ = Gain of low pass section

The frequency response for such a first order wide band pass filter is shown in the Fig. 3.10.4

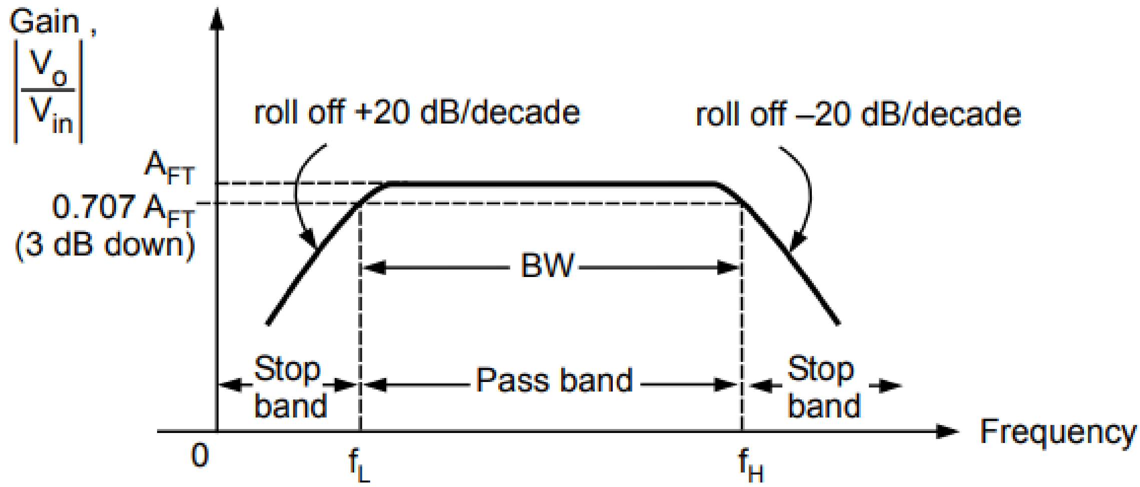



**Fig. 3.10.4 Frequency response**

**2. Narrow Band Pass Filter**

The narrow band pass filter uses only one op-amp as against two by wide band pass filter. It has following features :

i) It has two feedback paths.

ii) The op-amp is in the inverting configuration.

Due to the two feedback paths, it is called multiple feedback filter.

The Fig. 3.10.5 shows the circuit diagram of narrow band pass filter.

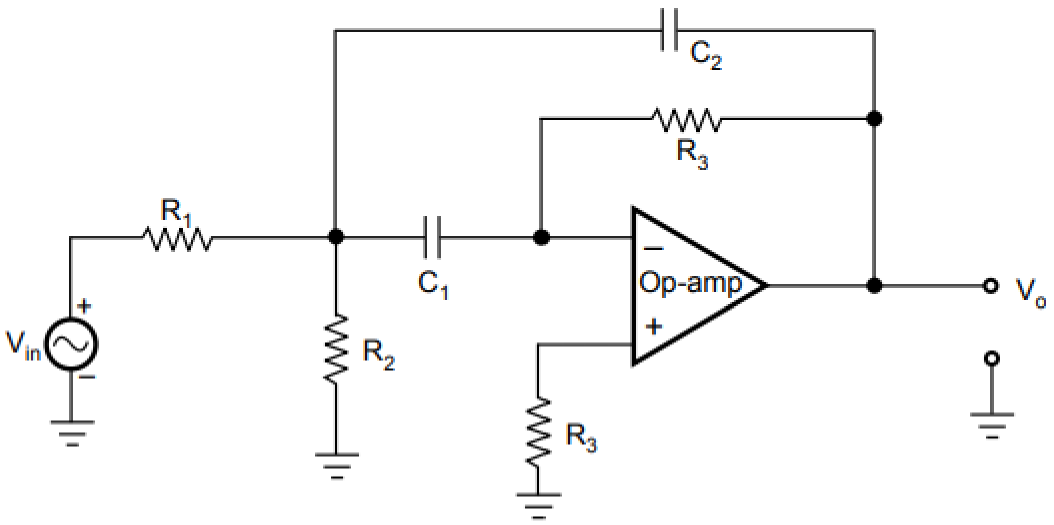



**Fig. 3.10.5 Narrow band pass filter**

As seen from Fig. 3.10.5, the input is applied to the inverting input terminal. Thus, op-amp is in inverting configuration. The resistance $R_3$ connected to non-inverting input terminal is offset compensating resistance.

The important parameters of the narrow band pass filter are $f_L$' $f_H$' the center frequency $f_{C'}$ the gain at the center frequency AF and the quality factor Q.

The relationship of components with the various parameters are given by the following expressions.

For simplifying the calculations, choose $C_1 = C_2 = C$.

$$R_1 = \frac{Q}{2\pi f_C C A_F} \quad \ldots (3.10.6)$$

$$R_2 = \frac{Q}{2\pi f_C C (2Q^2 - A_F)} \quad \ldots (3.10.7)$$

$$R_3 = \frac{Q}{\pi f_C C} \quad \ldots (3.10.8)$$

and $A_F = \frac{R_3}{2 R_1}$ = Gain at $f_C$ ... (3.10.9)

The gain $A_F$ must satisfy the equation,

$$A_F < 2Q^2 \quad \ldots (3.10.10)$$

Changing the centre frequency $f_C$ :

Let $f_C$ = Original frequency

$f_C$ = New centre frequency

The new centre frequency can be achieved by changing the resistance $R_2$. The new value of resistance say $R_2$, can be obtained as,

$R_2 = R_2 (f_C / f_C)$ ... (3.10.11)

This is an important advantage of the multiple feedback circuit, that $f_C$ can be changed without changing gain $A_F$ or bandwidth BW.

The frequency response of the narrow band pass filter is shown in Fig. 3.10.6.

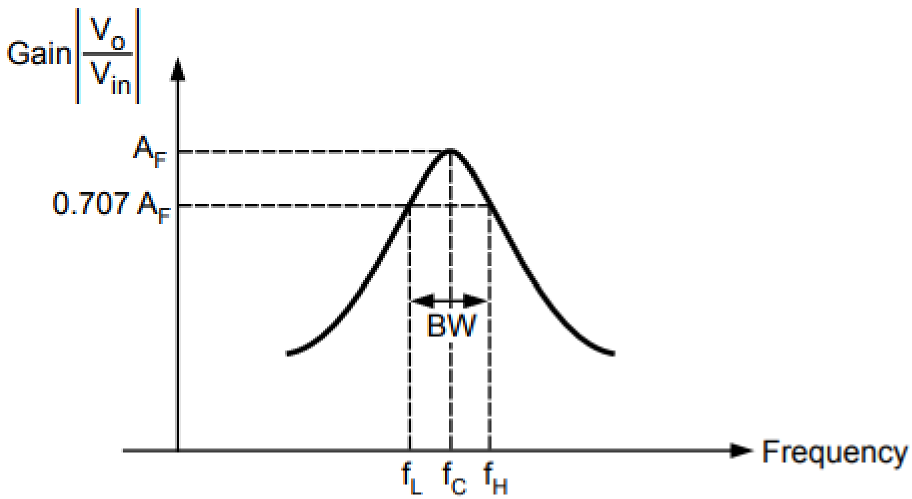



**Fig. 3.10.6 Frequency response**