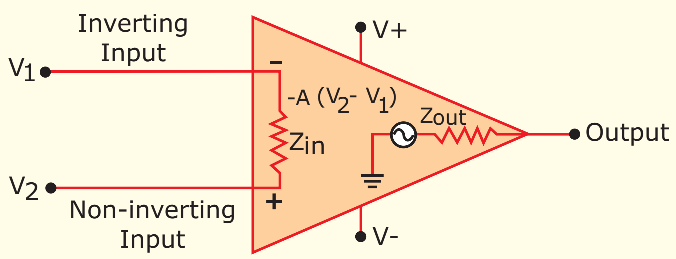
Active Filters

Active Filters:

Active Filters contain active components like operation difference between a "passive filter" and an "active filter" is amplification. Active filter generally uses an operational amplifier (OPAMP) has a high input impedance, a low output impedance and a voltage gain. Active Filters are generally , more easier to design; they produce good performance characteristics, accuracy, and low noise. OPAMP's are linear devices & are used in signal conditioning and filtering.

Operation amplifier is basically a three-terminal device which consists of two high impedance inputs, one is called the Inverting Input, marked with a "minus" sign ("-") and the other one is called the Non-inverting Input, marked with a "plus" sign ("+")

Equivalent Circuit for Ideal Operational Amplifiers:

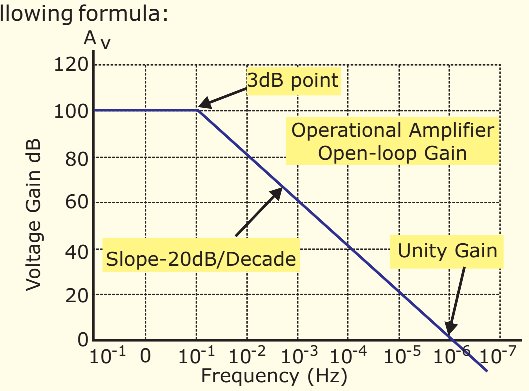


Operational Amplifier Idealized Characteristics:

- Its open loop gain is infinite i.e. When feedback is not used.
- Its input resistance is infinite i.e. It does not absorb any current from the input signal.
- Its bias current is zero.
- Its output resistance is zero.
- Its CMRR is infinite.
- Its input-offset voltage is zero..
- Its offset current is zero i.e. The difference between bias currents is zero.
- It can amplify any signal having any frequency i.e. From DC (zero frequency) to AC (infinite frequency).
- Its propagation delay is zero.

Open-loop Frequency Response Curve

The Voltage Gain (A) of the amplifier can be found using the following formula:



Voltage Gain, (A) $= \frac{V_{out}}{V_{in}}$ in dB

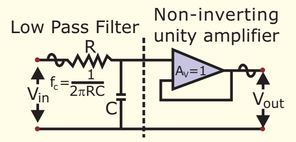
In Decibels (dB),

20 log (A) or 20 log $\frac{V_{out}}{V_{in}}$ in dB

Active Low Pass Filter:

The simplest from of a low pass active filter is to connect an inverting or non-inverting amplifier.

First Order Active Low Pass Filter:



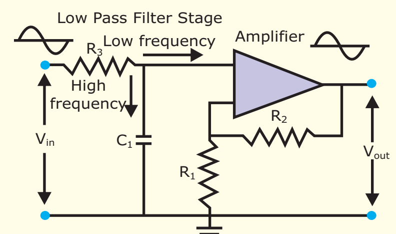
Low pass active Filter, consists of a passive RC filter stage providing a low frequency path to the input of a non-inverting operational amplifier. The amplifier is configured as a voltage-follower giving it a DC gain of one, AV = +1 or unity gen.

Advantage: OPAMP's high input impedance prevents excessive loading on the filters output while its low output impedance prevents the filter cut off frequency point from being affected by changes in the impedance of the load. Provides good stability to the filter.

Disadvantage: No voltage gain above one.

Active Low Pass Filter with Amplification:

Amplitude of the output is increased by the pass band gain. For a non-inverting circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R2) divided by its corresponding input resistor (R1) value and is given as:



DC Gain $= 1 + \frac{R_2}{R_1}$

Gain of first-order low pass filter:

Voltage Gain, $(A_v) = \frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$

where
A_F = the pass band gain of the filter $(1+R_2/R_1)$
f= the frequency of the input signal in Hertz, (Hz)
f_c = the cut off frequency in Hertz, (Hz)

Thus, the operation of low pass active filter Can be verified from the frequency gain equation as:

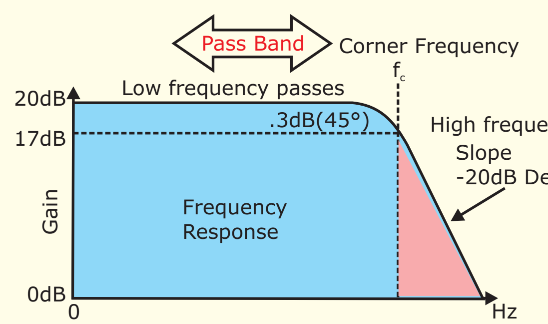
1. At very cut-off frequency, $f < f_c$, $\frac{V_{out}}{V_{in}} \cong F_F$
2. At the cut-off frequency, $f = f_c$, $\frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{2}} = 0.707A$
3. At very low frequency, $f > f_c$, $\frac{V_{out}}{V_{in}} < A_F$

Magnitude of Voltage Gain in (dB)

$A_V(dB) = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$ $\therefore -3dB = 20\log_{10}\left(0.707\frac{V_{out}}{V_{in}}\right)$

Frequency Response Curve

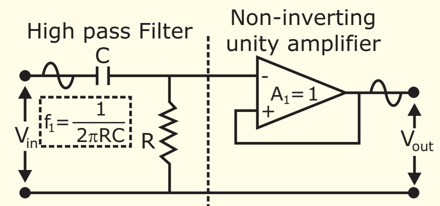
Gain $= 20\log\frac{V_{out}}{V_{in}}$



Active High Pass Filter

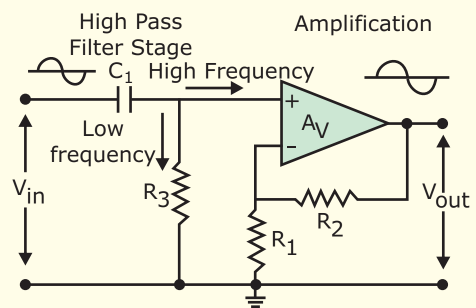
Active high pass filter is to connect an inverting or non-inverting operational amplifier to the basic RC high pass passive filter circuit.

First Order Active High Pass Filter



High pass active filter, consists or a passive RC filter stage providing a high frequency path to the input of a non-inverting operational amplifier. The amplifier is configured as a voltage follower giving it a DC gain of one, AV = +1 or unity gain Attenuates low frequency and passes high frequency signals. The frequency response of the circuit is the same as that of the passive filter, except that the amplitude of the signal is increased by the gain of the amplifier and for a non-inverting amplifier the value of the pass band voltage gain.

Active High Pass Filter with Amplification:



Amplitude of the output is increased by the pass band gain. For a non inverting circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R2) divided by its corresponding input resistor (R2) value and is given as:

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

High for an Active High Pass Filter

Voltage Gain, $(A_V) = \frac{V_{out}}{V_{in}} = \frac{A_F\left(\frac{f}{f_c}\right)}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$

Where:
A_V = the pass band gain of the filter, $(1+R_2/R_1)$
f = the frequency of the input signal in Hertz, (Hz)
f_c = the cut-off frequency in Hertz, (Hz)

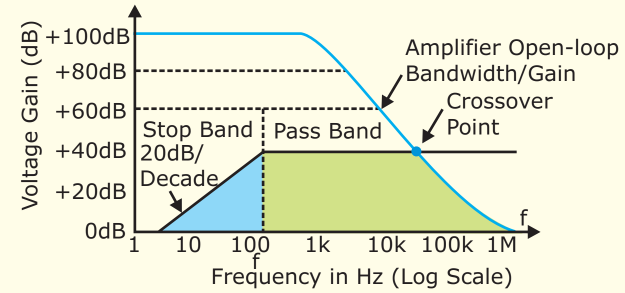
Just like the low pass filter, the operation of high pass active filter can be verified from the frequency gain equation as:

1. At very low frequencies, $f < f_c$, $\frac{V_{out}}{V_{in}} < A_F$
2. At the cut off frequency, $f = f_c$, $\frac{V_{out}}{V_{in}} = \frac{A_1}{2} = 0.707A_F$
3. At very high frequencies, $f > f_c$, $\frac{V_{out}}{V_{in}} \cong A_F$

Magnitude of Voltage Gain in (dB)

$A_V(dB) = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$ $\therefore -3dB = 20\log_{10}\left(0.707\frac{V_{out}}{V_{in}}\right)$

Frequency Response Curve

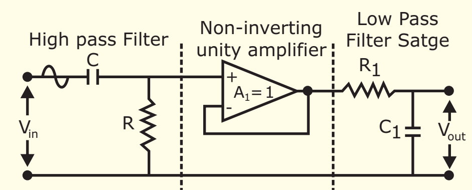


Active Band Pass Filter

Active Band Pass Filter can be made by cascading together a Low Pass Filter with a High Pass Filter.

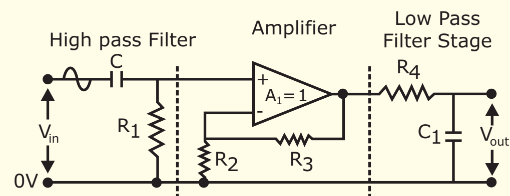
Active Band Pass Filter

Band pass active filter consists of two passive RC filter stage providing a high frequency path to the input of a non-inverting operational amplifier & Low frequency path at output of operational amplifier. The amplifier is configured as a voltage-follower giving a DC gain of one, AV = +1 or unity gain. The cut-off frequency of LPF is higher then cut-off frequency of HPF and at -3dB point determines "bandwidth" of band pass filter while attenuating any signals outside of these points. Individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. Advantage: producing a relatively flat asymmetrical pass band frequency response.



Active Band Pass Filter with Amplification:

Amplitude of the output is increased by the pass band gain. For a non-inverting circuit, the magnitude of the voltage gain for the filter is given as a function of the feedback resistor (R2) divided by its corresponding input resistor (R1) value and is given as:



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

Gain for an Active Band Pass Filter:

Voltage Gain, $(A_v) = \frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$

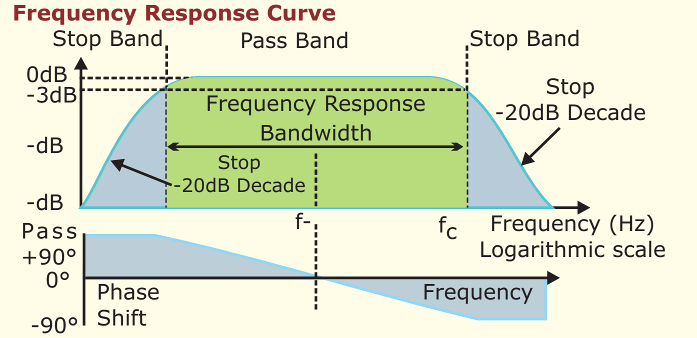
where
A_F = the pass band gain of the filter $(1+R_2/R_1)$
f= the frequency of the input signal in Hertz, (Hz)
f_c = the cut off frequency in Hertz, (Hz)

Frequency	High Pass	Low Pass
1. At very low frequencies, $f < f_c$,	$\frac{V_{out}}{V_{in}} < A_F$	$\frac{V_{out}}{V_{in}} \cong A_F$
2. At the cut off frequency, $f = f_c$,	$\frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{2}}$	$\frac{V_{out}}{V_{in}} = \frac{A_F}{\sqrt{2}}$
3. At very high frequencies, $f > f_c$,	$\frac{V_{out}}{V_{in}} \cong A_F$	$\frac{V_{out}}{V_{in}} < A_F$

Magnitude of Voltage Gain in (dB)

$A_V(dB) = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$ $\therefore -3dB = 20\log_{10}\left(0.707\frac{V_{out}}{V_{in}}\right)$

Frequency Response Curve



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