HIGH PASS FILTER :

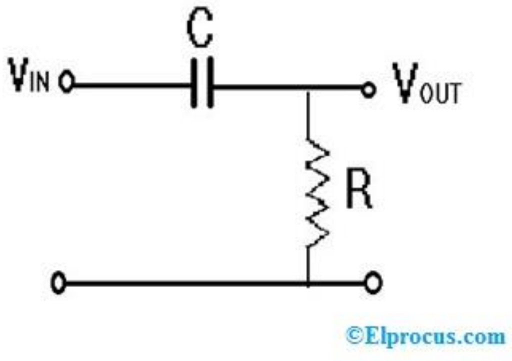
There was an era where while making a telephone call over distance places, one had to put his mouth very close to the transmitter, speak very slowly and very loudly so that message can be heard clearly by the person at the other end. Today, we can even make video calls over worldwide with high-quality resolutions. The secret of such a tremendous development of technology lies in Electrical filter theory and Transmission line theory. Electrical filters are circuits that pass only selected band of frequencies while attenuating other unwanted frequencies. One of such filters is High pass filter.

What is a High Pass Filter?

The definition of high pass filter is a filter which passes only those signals whose frequencies are higher than cutoff frequencies thereby attenuating signals of lower frequencies. The value of cutoff frequency depends on the design of the filter.

High Pass Filter Circuit

The basic High Pass Filter is built by a series connection of capacitor and resistor. While the input signal is applied to the capacitor, the output is drawn across the resistor.



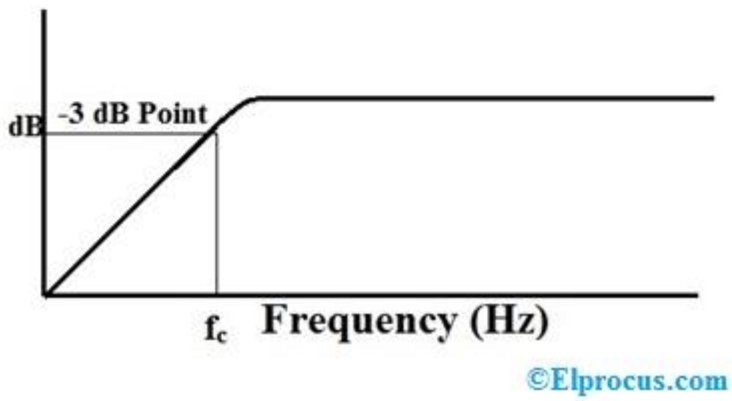
In this circuit arrangement, the capacitor has high reactance at lower frequencies so it acts as an open circuit to the low-frequency input signals until cutoff frequency 'fc' is reached. Filter attenuates all the signals below the cutoff frequency level. At frequencies above cut off frequency level reactance of the capacitor becomes low and it acts as a short circuit to these frequencies thereby allowing them to pass directly to the output.

Passive RC High Pass Filter

The above shown High Pass filter is also known as Passive RC High Pass filter as the circuit is built using only passive elements. There is no need of applying external power for working of the filter. Here capacitor is the reactive element and output is drawn across the resistor.

High Pass Filter Characteristics

When we talk about cutoff frequency we refer to the point in the frequency response of the filter where the gain is equal to 50% the peak gain of the signal .i.e. 3dB of the peak gain. In High Pass Filter gain increases with an increase in frequencies.



High Pass Filter Frequency Curve

This cutoff frequency fc depends on R and C values of the circuit. Here Time constant $\tau = RC$, the cutoff frequency is inverse proportional to the time constant.

Cutoff frequency = $1/2\pi RC$

Circuit gain is given by AV = Vout/Vin

.i.e. $AV = (Vout)/(V\ in) = R/\sqrt{(R^2 + Xc^2)} = R/Z$

At low frequency f: $Xc \rightarrow \infty$, Vout = 0

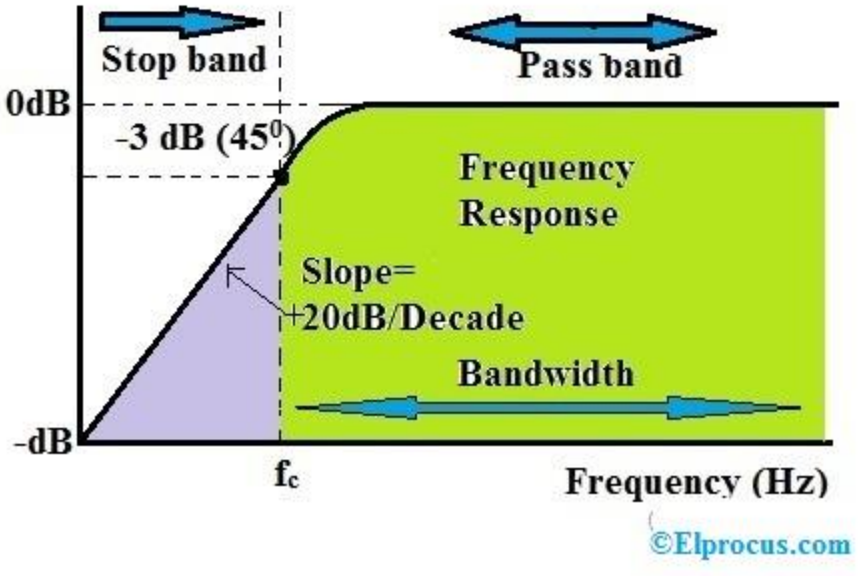
At high-frequency f: $Xc \rightarrow 0$, Vout = Vin

High Pass Filter Frequency Response or High Pass Filter Bode Plot

In high pass filter, all frequencies lying below the cutoff frequency 'fc' are attenuated. At this cut off frequency point we get -3dB gain and at this point reactance of the capacitor and resistor values will be same .i.e. R = Xc. Gain is calculated as

Gain (dB) = 20 log (Vout/Vin)

The slope of high pass filter curve is +20 d B/ decade .i.e. after passing cutoff frequency level the output response of the circuit increases from 0 to Vin at a rate of +20 dB per decade which is 6 dB increase per octave.



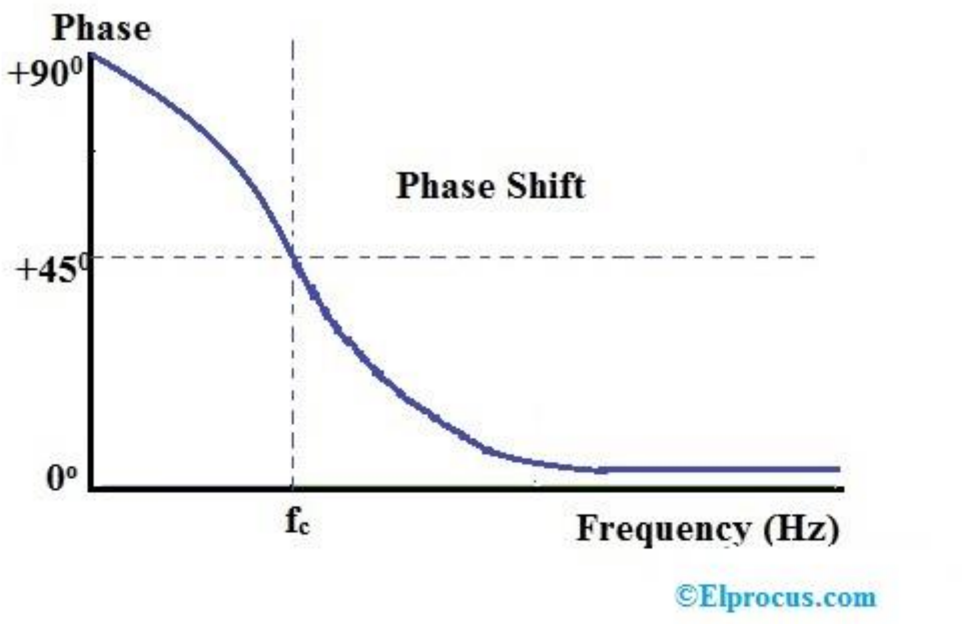
High Pass Filter Frequency Response

The region from the initial point to cutoff frequency point is known as stop band as no frequencies are allowed to pass. The region from above the cutoff frequency point. i.e. -3 dB point is known as the **passband**. At cutoff frequency, point output voltage amplitude will be 70.7% of the input voltage.

Here bandwidth of the filter denotes the value of frequency from which signals are allowed to pass. For example, if the bandwidth of the high pass filter is given as 50 kHz it means that only frequencies from 50 kHz to infinity are allowed to pass.

The phase angle of the output signal is +450 at the cut off frequency. The formula to calculate the phase shift of high pass filter is

$\emptyset = \arctan(1/2\pi fRC)$

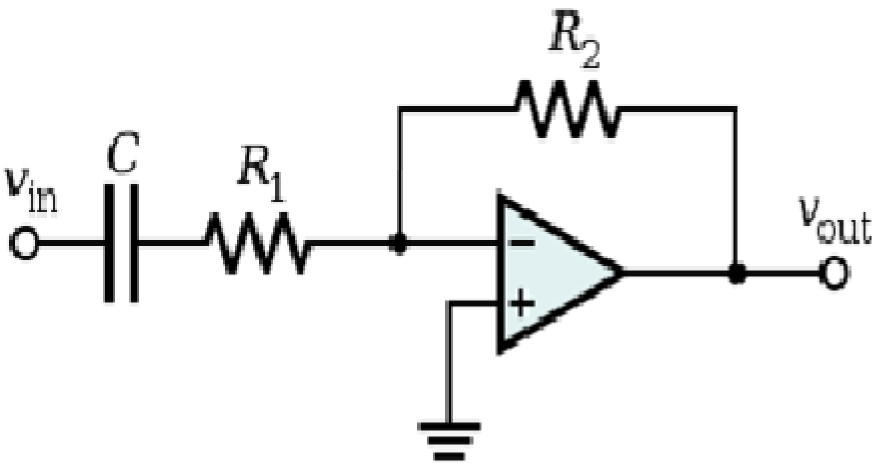


Phase Shift Curve

In practical application, the output response of filter does not extend to infinity. The electrical characteristic of the filter elements applies the limitation to the filter response. By proper selection of filter components, we can adjust the range of frequencies to be attenuated, the range to be passed etc…

High Pass Filter using Op-Amp

In this high pass filter along with passive filter elements, we add **Op-amp** to the circuit. Instead of getting an infinite output response, here the output response is limited by open loop **characteristics of the Op-amp**. Hence this filter acts as a **band-pass filter** with a cut off frequency which is defined by the bandwidth and gain characteristics of Op-amp.



High Pass Filter using Op-Amp

The open loop voltage gain of Op-amp acts as a limitation to the bandwidth of the amplifier. The gain of the amplifier reduces to 0 dB with the increase in input frequency. The response of the circuit is similar to passive high pass filter but here gain of the Op-amp amplifies the amplitude of the output signal.

The gain of the filter using non inverting Op-amp is given by:

$AV = Vout/Vin = (Af\ (f/fc))/\sqrt{(1+ (f/fc)^2)}$

where Af is passband gain of the filter = 1+(R2)/R1

f is the frequency of the input signal in Hz

fc is the cut off frequency

When low tolerance resistors and capacitors are used these High Pass Active filters provide good accuracy and performance.