OPERATION, APPLICATION, AND USES OF FILTERS

Filters: change the relative amplitudes of the various frequency components and/or their phase relationships

Filters are often used in electronic systems to emphasize signals in certain frequency ranges

Four Major Types of Filters

- Low-pass filter
- High-pass filter
- Band-pass filter
- Band-stop filter or Notch filter

Filtering Characteristics of Capacitors

The nature of the capacitance opposes the change in voltage across its terminal by storing energy in its electrostatic field.

Whenever the voltage tends to rise, the capacitor converts this voltage change to stored energy.

When the voltage tends to fall, the capacitor converts this stored energy back to voltage.

Filtering Characteristics of Inductors

The inductance provided by an inductor may be used as a filter, because it opposes a change in current through it by storing energy in its electromagnetic field.

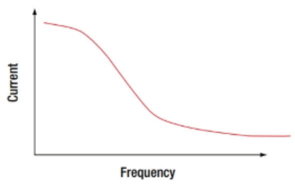
Whenever the current increases, the stored energy in the electromagnetic field increases

When the current through the inductor decreases, the inductor supplies the energy back into the circuit in order to maintain the existing flow of current.

Low-Pass Filter

1, A low-pass filter is a filter that passes low frequencies well

2, reduces higher frequencies



Frequency Response

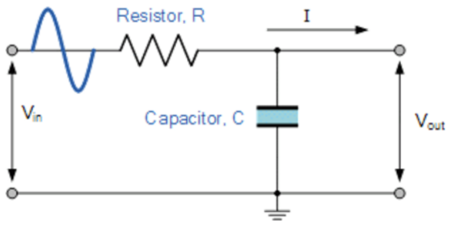
the low pass filter only allows low frequency signals from 0Hz to its cut-off frequency

An Inductive low-pass filter inserts an inductor in series with the load

capacitive low-pass filter inserts a resistor in series and a capacitor in parallel with the load low – pass filter

A **Low Pass Filter** circuit consisting of a resistor of 4700Ω 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 10,000Hz or 10kHz.

Voltage Output at a Frequency of 100Hz.



$$Xc = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 100 \times 47 \times 10^{-9}} = 33,863\Omega$$

$$V_{OUT} = V_{IN} \times \frac{Xc}{\sqrt{R^2 + X_C^2}} = 10 \times \frac{33863}{\sqrt{4700^2 + 33863^2}} = 9.9v$$

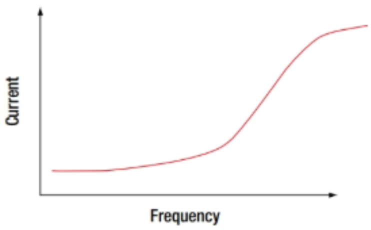
Voltage Output at a Frequency of 10,000Hz (10kHz)

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 10,000 \times 47 \times 10^{-9}} = 338.6\Omega$$

$$V_{OUT} = V_{IN} \times \frac{X_C}{\sqrt{R^2 + X_C^2}} = 10 \times \frac{338.6}{\sqrt{4700^2 + 338.6^2}} = 0.718v$$

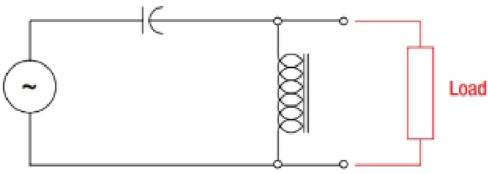
High-Pass Filter

A high-pass filter (HPF) is a filter that passes high frequencies well, but attenuates (reduces) frequencies lower than the cutoff frequency



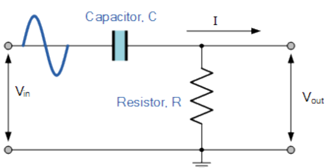
Frequency Response

An Inductive high-pass filter inserts an inductor in parallel with the load



High-pass Filter

capacitive high-pass filter inserts a resistor in parallel and a capacitor in series with the load.



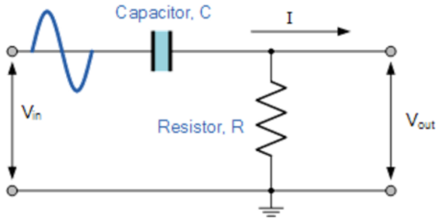
Cut-off Frequency

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

$$Phase\ Shift\ \ \phi\ = arctan\ \frac{1}{2\pi fRC}$$

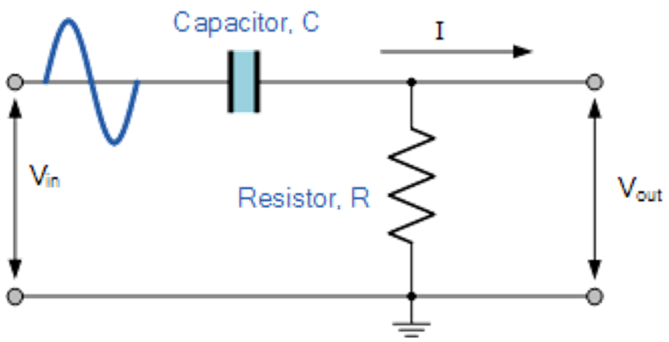
Calculate the cut-off or “breakpoint” frequency (f_c) for a simple passive high pass filter consisting of an 82pF capacitor connected in series with a 240kΩ resistor.

$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi\ x\ 240{,}000 x 82 x 10^{-12}} = 8{,}087\ Hz\ or\ 8kHz$$



Filters

High-Pass Filter



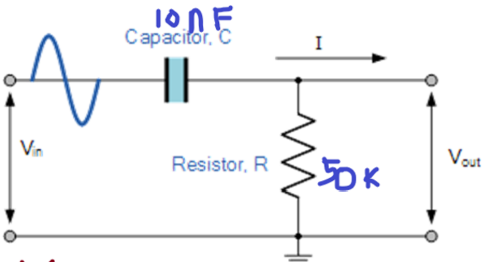
$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{R}{\sqrt{R^2 + Xc^2}} = \frac{R}{Z}$$

$$\text{at low } f:\ Xc \to \infty,\ \ Vout = 0$$
$$\text{at high } f:\ Xc \to 0,\ \ Vout = Vin$$

Filters

High-Pass Filter

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



$f_{co} = 318\ Hz$

$f_1 = 10\ Hz$

$f_2 = 10\ kHz$

$X_c = 1.6\ M\Omega$ / 1600

$Z = \sqrt{R^2 + X_c^2} = 1.61\ M\Omega$

$V_{out} = R \times I = \frac{R}{Z} \times V_{IN} = 0.03\ V_{IN} = 0.03 \times 10V = 0.3V$

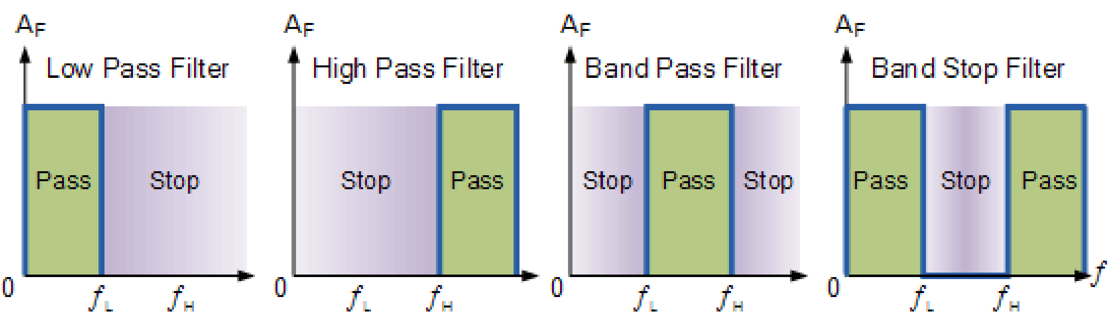
band pass filter

A band-pass filter is basically a combination of a high-pass and a low-pass. ▪

There are some applications where a particular range of frequencies need to be singled out or filtered from a wider range of frequencies. ▪

Band stop filter

A band-stop filter or band-rejection filter is a filter that passes most frequencies unaltered but attenuates those in a range to very low levels. ▪



Frequency	XL	XC	VL	VC
Low	Low	High	Low	High
High	High	Low	High	Low

Filters: -

Low Pass Filter Pass stop (VC)

High Pass Filter Stop pass (VL)

Band Pass Filter Stop pass stop

Band stop Filter Pass stop pass