A. ABOUT FILTERS

An electric filter is a frequency-selecting circuit designed to pass a specified band of frequencies while attenuating signals of frequencies outside this band. Filters may be either active or passive depending on the type of elements used in their circuitry. Passive filters contain only resistors, capacitors, and inductors. Active filters employ transistors or op-amps in addition to resistors and capacitors. Active filters offer several advantages over passive filters. Since the op-amp is capable of providing a gain, the input signal is not attenuated as it is in a passive filter. Because of the high input and low output resistance of the op-amp, the active filter does not cause loading of the source or load.

There are four types of filters: low-pass, high-pass, band-pass, and band-reject filters. The figure below shows the frequency response characteristics for a low- and high-pass filter.

A low-pass filter has a constant gain \(=\frac{V_{out}}{V_{in}}\) from 0 Hz to a high cut off frequency \(f_H\). This cut off frequency is defined as the frequency where the voltage gain is reduced to 0.707, that is at \(f_H\) the gain is down by 3 dB; after that \((f > f_H)\) it decreases as \(f\) increases. The frequencies between 0 Hz and \(f_H\) are called pass band frequencies, whereas the frequencies beyond \(f_H\) are the so-called stop band frequencies. A common use of a low-pass filter is to remove noise or other unwanted high-frequency components in a signal for which you are only interested in the dc or low frequency components. Low-pass filters are also used to avoid aliasing in analog-digital conversion (which we will encounter in a few weeks).

A high-pass filter has a stop band for \(0 < f < f_L\) and where \(f_L\) is the low cut off frequency. A common use for a high-pass filter is to remove the dc component of a signal for which you are only interested in the ac components (such as an audio signal).

A bandpass filter has a pass band between two cut off frequencies \(f_H\) and \(f_L\), \((f_H > f_L)\), and two stop bands \(0 < f < f_L\) and \(f > f_H\). The bandwidth of a bandpass filter is equal to \(f_H-f_L\). Recall that we used a tunable bandpass filter to do harmonic spectrum analysis several weeks ago.
As shown in the above figure, the actual response curves of the filters in the stop band either steadily decrease or increase with increase of frequency. The roll-off rate, measured at [dB/decade] or [dB/octave] is defined as rate change of power at 10 times (decade) or 2 times (octave) change of frequency in the stop band. The “First-order” filters attenuate voltages in the stop band 20 dB/decade (for example, a first-order lowpass filter would attenuate a signal at a frequency 100 times (2 decades) higher than $f_H$ by 40 dB. The second-order filters attenuate by about 40 dB/decade.

A simple low pass filter circuit employing resistors and capacitors is shown at the right:

The cutoff frequency is $f_H=1/(2\pi RC)$. The power output is proportional to $1/(1+(f/f_H)^2)$. In decibel unit, the roll-off rate for the first order filter is typically $20\log(10)=20$ dB/decade or 6dB/octave as shown in the semi-log plot on the right of dB vs $f$.

Similarly, a simple high pass filter is

a) If a capacitor is $C=0.01 \, \mu F$, and $R=4 \, k\Omega$, what is the cutoff frequency?

b) If a capacitor is $C=0.01 \, \mu F$, and $R=1 \, k\Omega$, what is the cutoff frequency?

c) What is the typical roll-off rate in dB/decade for the first order filter?

Acoustic PRELAB 12: Active Filters