Introduction to Measurement Systems: Passive and Active Filters

LA-CoNGA physics

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1 Background

1.1 Passive filters

The impedance of an inductor is proportional to frequency and the impedance of a capacitor is inversely proportional to frequency. These characteristics can be used to select or reject certain frequencies of an input signal. This selection and rejection of frequencies is called filtering, and a circuit which does this is called a filter.

If a filter passes high frequencies and rejects low frequencies, then it is a high-pass filter. Conversely, if it passes low frequencies and rejects high ones, it is a low-pass filter.

Filters, like most things, aren't perfect. They don't absolutely pass some frequencies and absolutely reject others. A frequency is considered passed if its magnitude (voltage amplitude) is within 70% (or $1/\sqrt{2}$ of the maximum amplitude passed and rejected otherwise. The 70% frequency is called corner frequency, roll-off frequency or half-power frequency.

The corner frequency for RC filter is:

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

1.2 Active filters

Consider the circuit presented in figure 1. The frequency response of the filter is the same as for the simple passive low-pass filter with the addition of the op-amp for gain control and amplification. The basic RC low-pass filter provides a low-frequency path by connecting it at the non-inverting input of the operational amplifier.

The amplitude of the output signal is increased in the pass-band with gain A which is given as a function dependent on the input resistor R_1 and feedback resistor R_2.

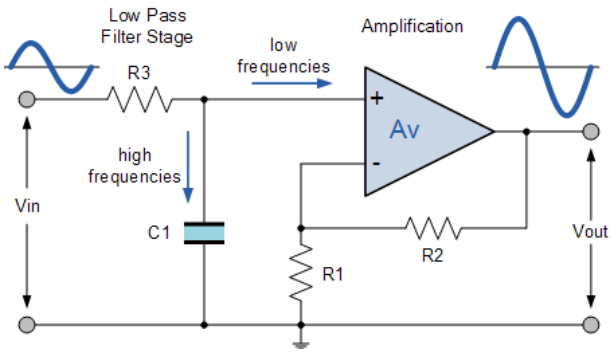

Figure 1: Active Low Pass Filter with Gain Control circuit

Therefore, gain of the first-order low pass filter as a function of frequency will be:

$$V_{gain} = \frac{V_{out}}{V_{in}} = \frac{A}{\sqrt{1 + \left(\frac{f}{f_c}\right)^2}} \tag{2}$$

Where A is the gain of the op-amp, f is the frequency of the input signal and f_c is the cut-off frequency.

2 Activities

1. Design a RC circuit with $R = 1K\Omega$ and $C = 1\mu F$ Perform an AC analysis and determine:
   - The f_c frequency
   - The slope of the attenuation zone in dB per decade.
2. Design an active filter with the same characteristics as $RCfilterabove$ and a gain $A = 10$
   - Compare the characteristics of the two circuits
3. Design a Second order low-pass filter and compare the characteristics with the previous.