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EE1200 - ELECTRIC CIRCUITS LAB

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1 BAND-PASS FILTER USING SALLEN-KEY SECOND-ORDER FILTERS

1.1 AIM :

- To design and implement a band-pass filter using separate Sallen-Key Low Pass Filter (LPF) and High Pass Filter (HPF) .
- To analyze and compare the frequency response of LPF, HPF, and the final band-pass filter.
- To plot the magnitude response (gain vs frequency) of all the three filters.

1.2 APPARATUS REQUIRED :

- Breadboard
- Op-Amps
- Four resistors
- Four capacitors
- Oscilloscope
- Digital function generator
- DC Power supply
- Connecting wires

1.3 THEORY :

A bandpass filter allows signals within a specific frequency range (*passband*) to pass while attenuating frequencies outside this range. This can be achieved by cascading a high-pass filter (HPF) and low-pass filter (LPF), where:

- HPF sets the lower cutoff frequency (f_{low})
- LPF sets the upper cutoff frequency (f_{high})
- Bandwidth $B = f_{high} - f_{low}$

The combined frequency response exhibits:

- -20 dB/decade roll-off below f_{low}
- -20 dB/decade roll-off above f_{high}
- Flat response between f_{low} and f_{high}

For first-order filters, the transfer functions are:

$$H_{HP}(s) = \frac{sRC_{HP}}{1 + sRC_{HP}} \tag{1}$$

$$H_{LP}(s) = \frac{1}{1 + sRC_{LP}} \tag{2}$$

The combined bandpass transfer function becomes:

$$H_{BP}(s) = H_{HP}(s) \cdot H_{LP}(s) = \frac{sRC_{HP}}{(1 + sRC_{HP})(1 + sRC_{LP})} \tag{3}$$

The cutoff frequencies are determined by:

$$f_{low} = \frac{1}{2\pi R_{HP}C_{HP}} \tag{4}$$

$$f_{high} = \frac{1}{2\pi R_{LP}C_{LP}} \tag{5}$$

- Cascading order affects roll-off slope (-40 dB/decade for second-order)
- Component tolerance impacts actual cutoff frequencies
- Loading effects between stages may require buffer amplifiers [5][8]
- Quality factor $Q = \frac{f_0}{B}$, where $f_0 = \sqrt{f_{low}f_{high}}$

The ideal bandpass response can be represented as:

$$|H(f)| = \begin{cases} 1 & \text{if } f_{low} \leq f \leq f_{high} \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

A Sallen-key second order is an active filter topology made using operational amplifiers. It provides a Butterworth, Bessel or Chebyshev response based on component selection. The corresponding transfer function is given by -

$$H(s) = \frac{A}{s^2 + \frac{\omega_c}{Q}s + \omega_c^2} \tag{7}$$

$$\omega_c - \text{ Cut-off frequency } Q - \text{ Quality Factor} \tag{8}$$

1.4 CIRCUIT DESIGN :

The three types of filters are shown in Figure 1, Figure 2 and Figure 3

1.5 PROCEDURE :

- Connect the HPF circuit as shown in the circuit diagram.
- A sine wave input is given using the digital function generator. The input frequency is varied and the output voltage is measured.
- The gain value is recorded for different frequencies, and is plotted against frequency (Bode Plot).
- Repeat the same steps with LPF and Bandpass filters.

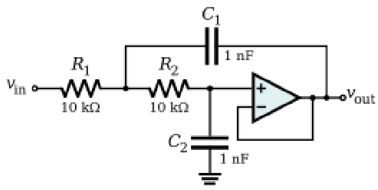

Figure 1: Low Pass Filter

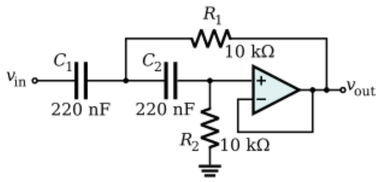

Figure 2: High Pass Filter

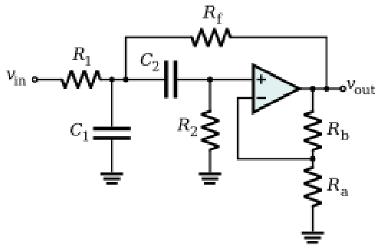

Figure 3: Band Pass Filter

1.6 OBSERVATION :

- The frequency response of HPF, LPF and Bandpass filters can be seen in the figures attached.
- Experimental cutoff frequency =
- Theoritical cut-off frequency =
- Frequency range of Bandpass filter =

1.7 RESULT :

- Cut-off frequency =
- Roll-off slope =
- Phase difference goes from 90 to 0