Lab 5: Low Pass Filter Design and Implementation

1. Task:

A filter removes unwanted components or features from a signal. It generally involves removing some frequencies from the signal in order to suppress the interfering signals and remove the background noise.

In this task you will be designing a low-pass filter and implementing it using an operational amplifier. This lab involves: a) How to design a first order active low-pass filter; b) Sallen-key Low Pass Filter; c) How to implement a low pass filter to remove harmonics from a signal.

2. Pre-Lab:

Active Filter:

An active filter is a type of analog electronic filter, distinguished by the use of one or more active components such as voltage amplifiers or buffer amplifiers. The transfer function *H(s)*of a filter is the ratio of the output signal *Y(s)*to the input signal *X(s)* as a function of the complex frequency '*s*'.

$$H(s) = \frac{Y(s)}{X(s)} \tag{1}$$

The transfer function and the cut-off frequency of the first order active low pass filter shown in Figure 1 can be represented as follows:

- Transfer Function: $$\frac{v_o(s)}{v_s(s)} = -\frac{R}{R_1}\frac{1}{(1+sCR)} \tag{2}$$

- Cut-off Frequency: $$f_{3db} = \frac{1}{2\pi RC} \tag{3}$$

The transfer function and the design equations of the Sallen-key low pass filter shown in Figure 2 can be represented as follows:

- Transfer Function: $$\frac{v_o(s)}{v_s(s)} = \frac{\frac{K}{(RC)^2}}{s^2 + s\left(\frac{3-K}{RC}\right) + \frac{1}{(RC)^2}} = \frac{H_0\omega_0^2}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2} \tag{4}$$

$$\omega_0 = \frac{1}{RC}$$

➢ Design Equations:

$$\frac{1}{Q} = 3 - K \qquad (5)$$

$$H_0 = K$$

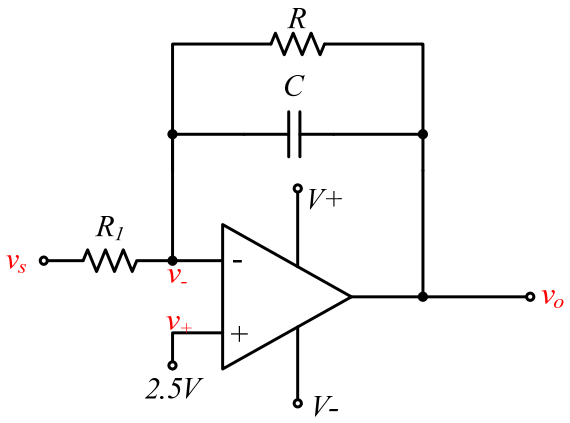

Figure 1: First Order Active Low-Pass Filter

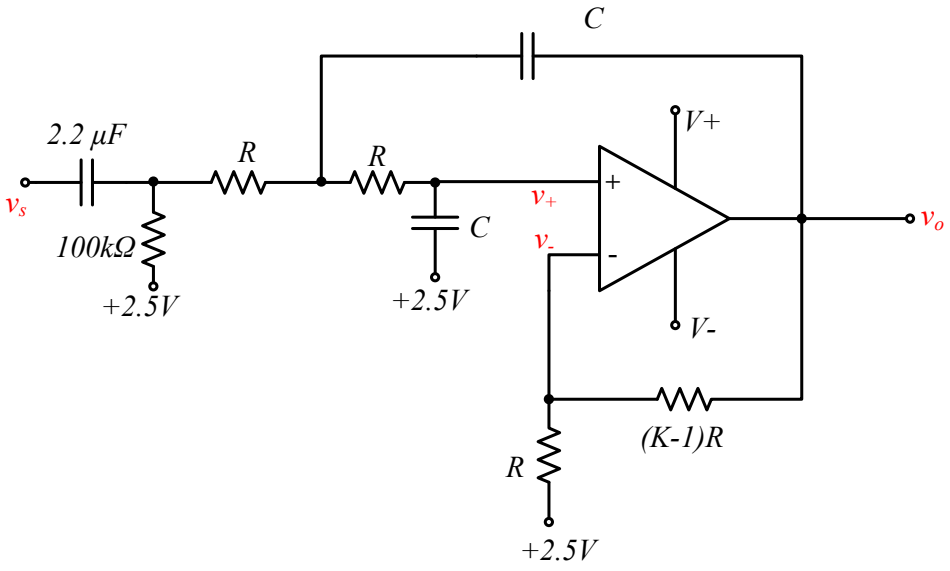

Figure 2: Sallen-key Active Low-Pass Filter

In this lab, you will learn how to find out these parameters from the components given and to verify it experimentally.

3. Resources:

Table 1: List of Hardware

Name	Qty	Description
Signal Generator	1	To generate sinusoidal,square,triangle waveforms
Oscilloscope	1	To view the output and input waveforms
NI Elvis	1	Hardware test platform
DC Power Supply	1	Provide a constant voltage supply

Table 2: Component List

Name	Qty	Description
LM358	1	Operational Apmplifier
1/4W Resistor	-	Use resistors as mentioned in lab procedure
Capacitor	2	10 nF Ceramic Capacitor

4. Lab procedure and analysis:

4.1 First Order Active Low-Pass Filter

1. Build the circuit on breadboard as shown in Figure.1. Choose C as 10nF, design R1 and R such that the 1st order active low pass filter exhibits gain of 3dB and cut-off frequency of 1kHz.

2. Connect signal generator to generate v_s: a sinusoidal signal with peak to peak amplitude of 100mV and frequency 50 Hz. Use oscilloscope to measure and record the peak to peak magnitude of v_o. Repeat this step for different frequencies to complete Table 3.

3. On the given semilog graph paper, plot gain (dB) versus frequency (Hz). Estimate the filter cutoff frequency from the plot.

4.2 Sallen-key Active Low-Pass Filter

1. Build the Sallen-key low pass filter circuit on breadboard as shown in Figure.2. Choose C as 10nF, design K and R such that the filter has a Q of 0.7071 and cut-off frequency of 5kHz.
2. Connect signal generator to generate v_s: a sinusoidal signal with peak to peak amplitude of 100mV and frequency 50 Hz. Use oscilloscope to measure and record the peak to peak magnitude of v_o. Repeat this step for different frequencies to complete Table 4.
3. On the same semilog graph paper used for **4.1**, plot gain (dB) versus frequency (Hz). Estimate the filter cutoff frequency from the plot.