Indian Institute of Technology Hyderabad

Analog Electronics and Integrated Circuits

Filters

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1 BandPass Filter with Sallen Key Topology

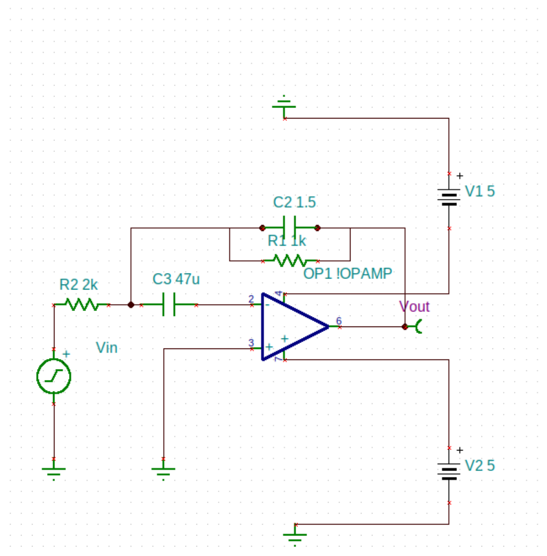

Figure 1: Bandpass filter with Sallen Key Topology

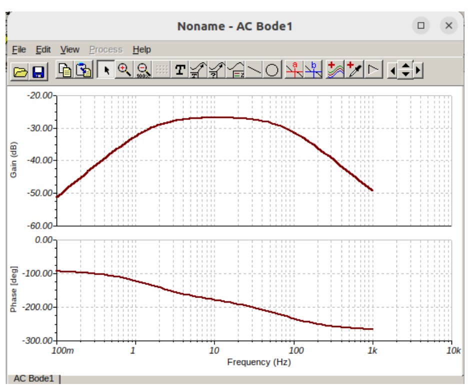

Figure 2: Bode Plot or AC Transfer Characteristics of the filter

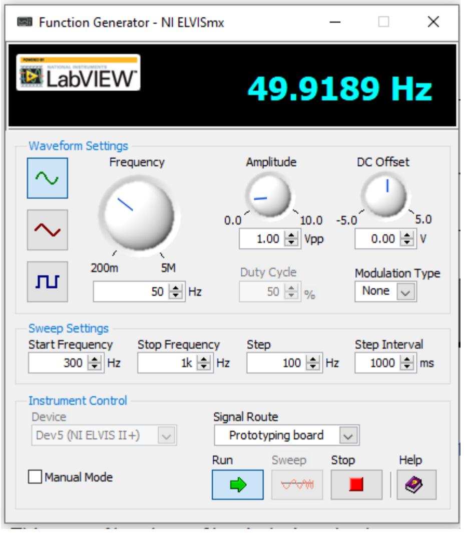

Figure 3: Function generator input at 50Hz

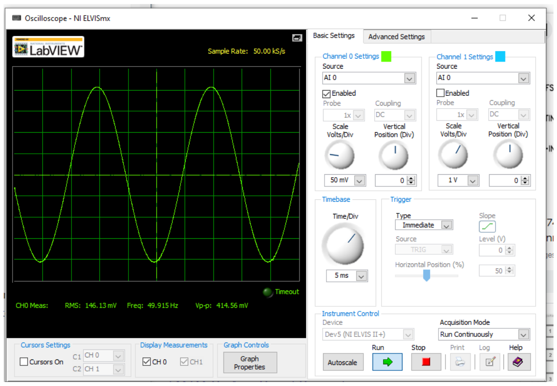

Figure 4: Output signal at 50Hz

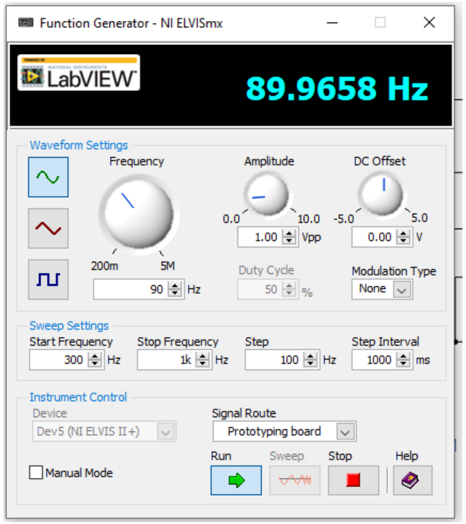

Figure 5: Function generator input at 90Hz

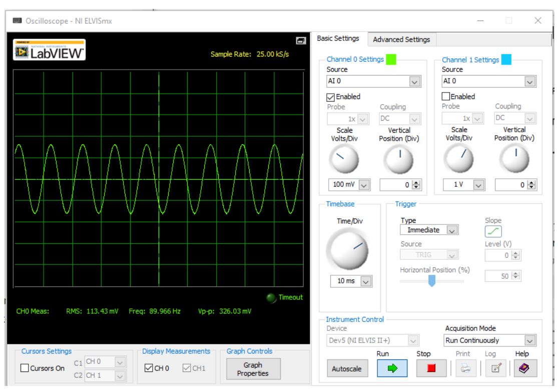

Figure 6: Output signal at 90Hz

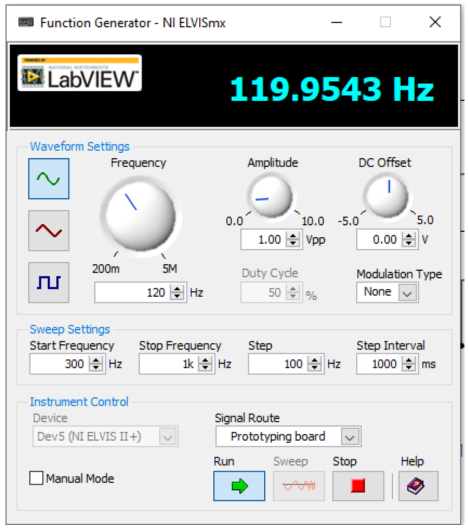

Figure 7: Function generator input at 120Hz

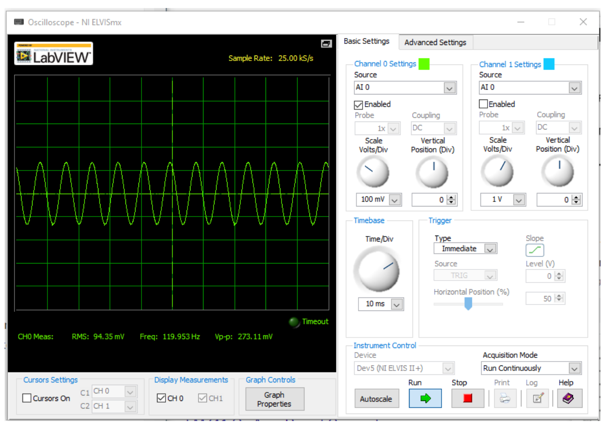

Figure 8: Output signal at 120Hz

Since the circuit used is of the second order, the roll-off rate is 40 dB/decade. The decrease in amplitude can be explained by the magnitude of the bode plot, which is always less, thus showing attenuation of the input signal.

The phase shift can also be explained by the phase part of the bode plot:

$$f_0 = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

For the given values:

$$f_0 = 10\,\text{Hz} \quad f_l = 1\,\text{Hz} \quad f_h = 100\,\text{Hz}$$

$$Q = \frac{1}{3 - \frac{R_2}{R_1}}$$

For the given values:

$$Q = 0.5$$

The higher the quality factor, the more the roll-off rate. This can be observed from the rate of decrease of the slope of the magnitude of the bode plot after the cutoff frequency of 1Hz and 100Hz.

The transfer function and the stability of the poles will be explained later in the doc

2 Low Pass Filter with Sallen Key Topology

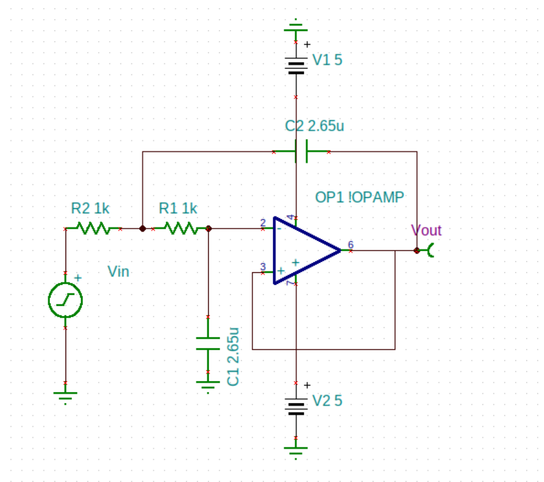

Figure 9: Low Pass Circuit

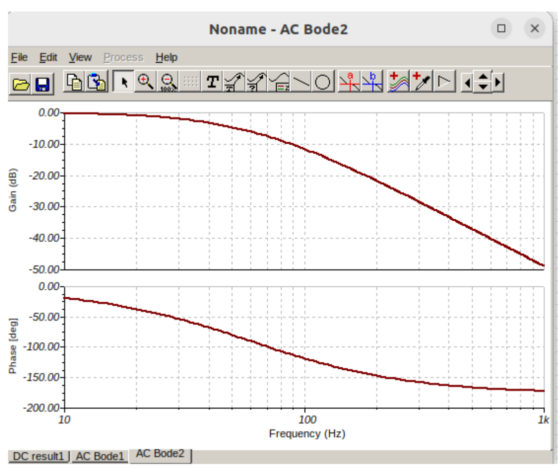

Figure 10: AC Transfer Characteristics of Low Pass Filter

$$f_0 = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

The following inferences can be made from the bode plot:

The magnitude of the bode plot explains the attenuation of the output signal on increasing frequency, thus showing its low pass characteristics.

The phase shift character is seen to be more or less linear. Since it is an implementation of a second-order filter, the roll-off rate is 40dB/decade.

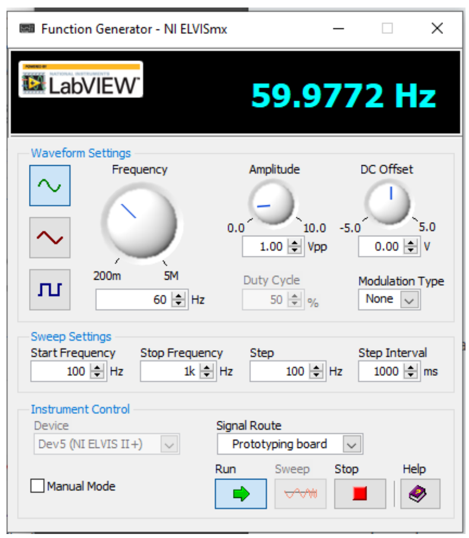

Figure 11: Function generator input at 60Hz

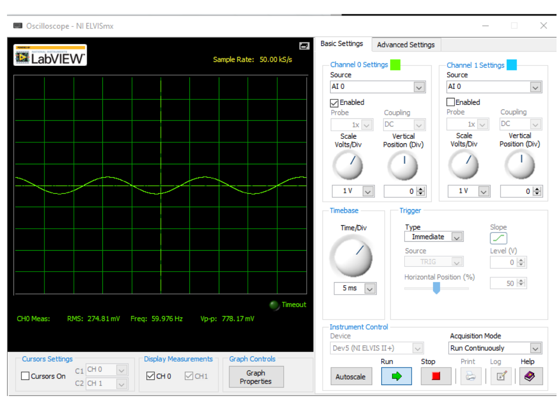

Figure 12: Signal

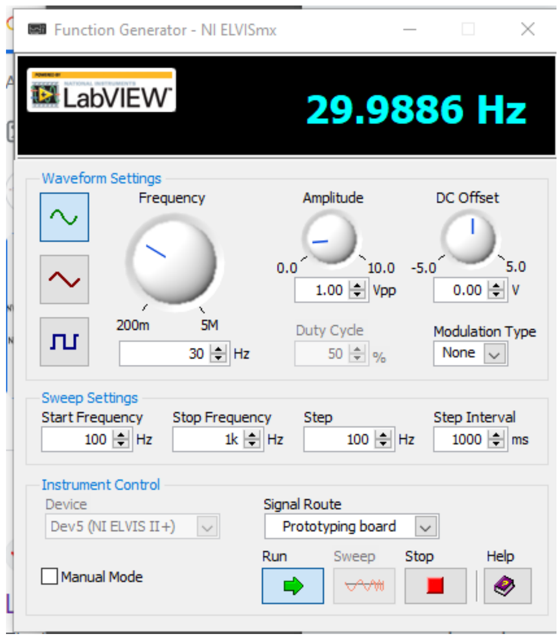

Figure 13: Function generator input at 30Hz

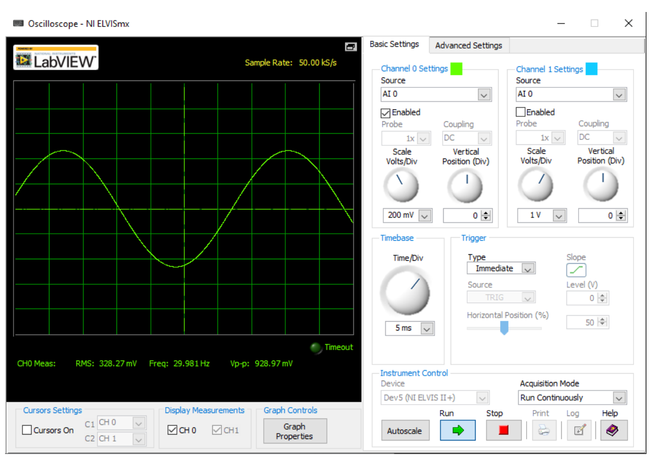

Figure 14: Signal

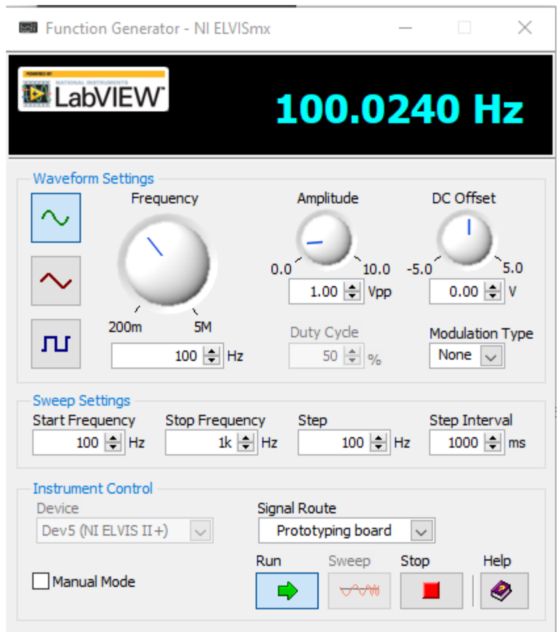

Figure 15: Function generator input at 100Hz

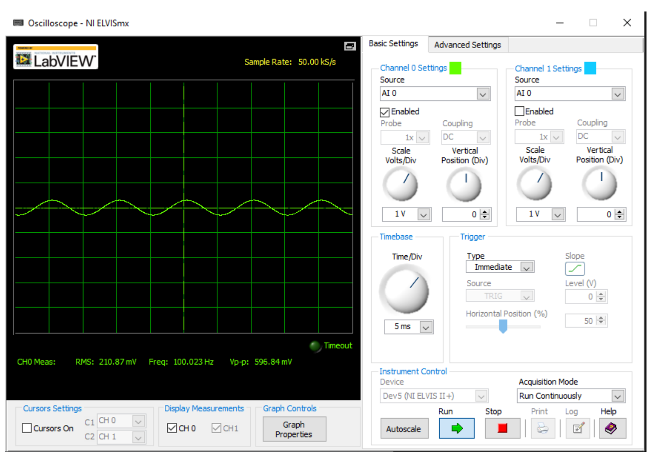

Figure 16: Signal

1 Transfer Function

Low Pass:

$$\frac{v_{in} - x}{R_1} + \frac{v_0 - x}{R_2} + (v_0 - x)C_2 s = 0$$

$$\frac{v_0 - x}{R_2} + v_0 C_1 s = 0$$

Solving, we have For the Low Pass filter, the transfer function $H(s)$ is given by:

$$H(s) = \frac{1}{c_1 c_2 R_1 R_2 s^2 + s c_1 (R_1 + R_2) + 1}$$

This equation describes the relationship between the input (v_{in}) and output (v_0) signals in the Low Pass filter circuit.

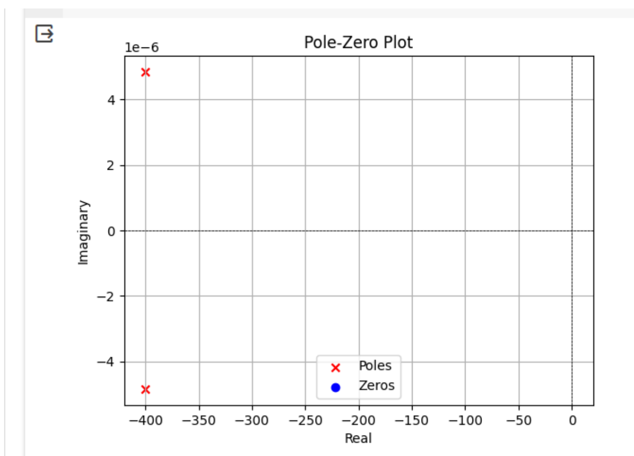

Figure 1: Pole Zero Plot for Low Pass Filter

Band Pass:

$$v_{in} - iR_1 - \frac{i}{C_1 s} - \frac{i}{C_2 s(1 + C_2 s)} = V_0$$

$$i = \frac{v_{in}}{R_1 + \frac{1}{c_1 s}}$$

on solving we get

$$H(s) = -\frac{c_1}{c_2} \cdot \frac{1}{(R_1 C_1 s + 1)(R_2 C_2 s + 1)}$$

This equation describes the relationship between the input (v_{in}) and output (V_0) signals in the High Pass filter circuit.

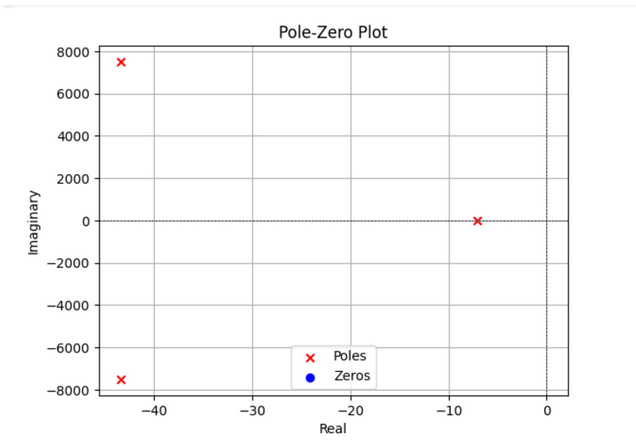

Figure 2: Pole Zero Plot for High Pass Filter

As seen in both the plots, the poles have negative real value, thus the design is stable.

For the Python code generating these plots, refer to https://colab.research.google.com/drive/1koj8sK5V5i7SiOVdr0mSccGSmV1wG-v0?authuser=1#scrollTo=-b5ql538-t14.