Aim ↬ To design and obtain the frequency response of second order Low Pass Filter [LPF].

Equipment Required ↬

Resistance, Potentiometer, Capacitor, IC 741 OP-AMP, Function Generator, CRO, Breadboard & connecting wires.

Theory ↬

A low-pass filter allows signals with frequencies lower than a specified cut-off frequency f_H to pass through while attenuating frequencies higher than f_H. At the cut-off frequency, the gain of the LPF is reduced to 70.7% (or -3 dB) of its maximum value. This point, where the filter transitions from passing to attenuating frequencies, is crucial for defining the filter's performance.

Roll-off Rate and Filter Order ↴

Beyond the cut-off frequency, the gain of a second-order LPF decreases at a rate of 40 dB/decade or 12 dB/octave. This indicates that for every tenfold increase in freq, the gain drops by 40 dB, or for every doubling of freq, it drops by 12 dB.

- **First-order LPF**: Exhibits a roll-off rate of 20 dB/decade or 6 dB/octave.
- **Second-order LPF**: Exhibits a steeper roll-off rate of 40 dB/decade or 12 dB/octave.

Higher-order filters continue to exhibit even steeper roll-offs. This rate of roll-off is characteristic of a second-order LPF and is crucial for effective frequency attenuation.

Mathematical Expression ↴

$$f_H = \frac{1}{2\pi\sqrt{R_2R_3C_2C_3}}$$

For simplicity, in a circuit where $R2 = R3 = R$ and $C2 = C3 = C$, the cut-off frequency is given by:

$$f_H = \frac{1}{2\pi RC}$$

This formula derives from the basic principles of filter design, where the cut-off frequency is inversely proportional to the product of resistance and capacitance.

Practical Considerations ↴

The cut-off frequency is also known as the -3 dB frequency, break frequency, or corner frequency. It is a critical parameter in determining how effectively the filter can separate desired signals from unwanted high-frequency noise.

In practical applications, LPFs are used to filter out high-frequency noise from signals, ensuring that only the relevant lower-frequency components are processed. This is essential in audio processing, signal conditioning, and many other electronic applications.

Circuit Diagram ↬

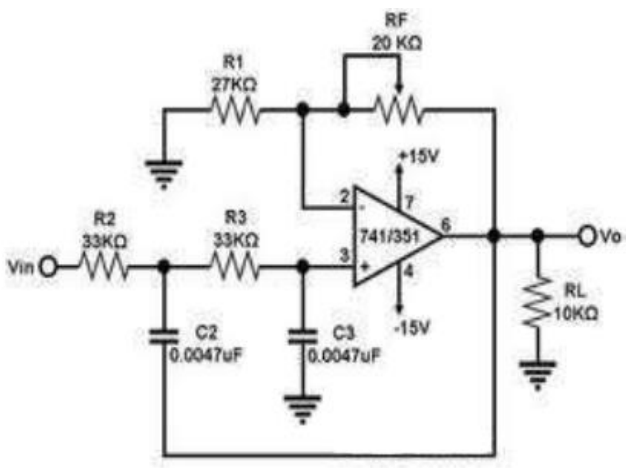

Fig. i) Second Order Low Pass Filter

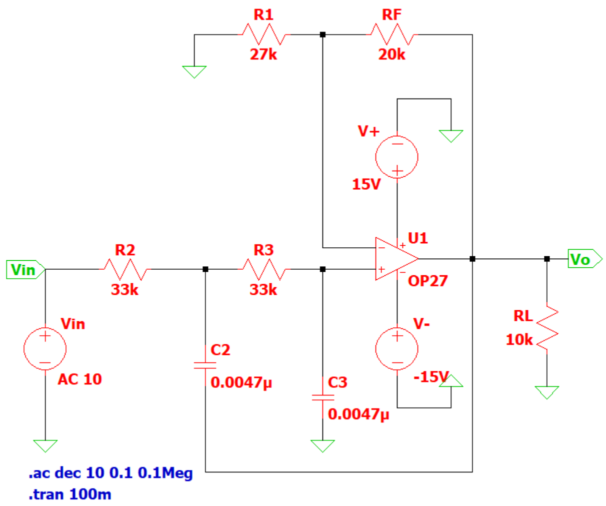

Fig. ii) LTSpice Implementation

Observation Table ↬

- **Simulation Data ↪**

S.No.	Input Freq f [Hz]	Gain Magnitude $\left\|\frac{V_0}{V_i}\right\|$	Magnitude in dB $20log\left\|\frac{V_0}{V_i}\right\|$
1	0.1	1.74	4.81
2	1	1.74	4.81
3	10	1.74	4.83
4	100	1.73	4.76
5	1K	1.42	3.04
6	10K	18.4m	-34.7
7	100K	184μ	-74.7

Graphs ↬

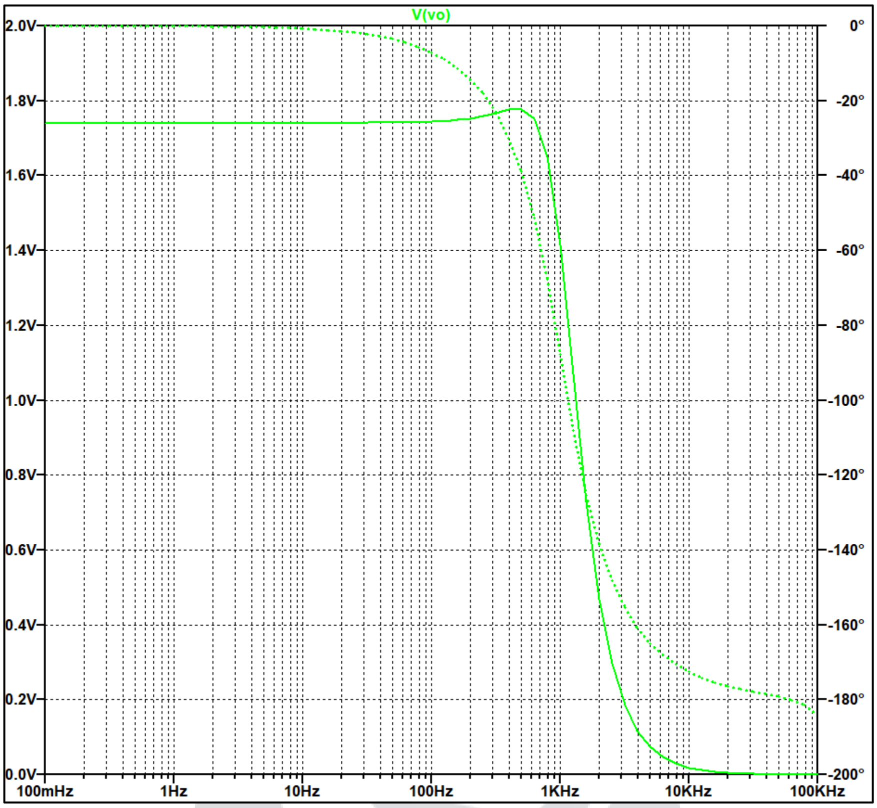

Fig. iii) Frequency Response [Linear]

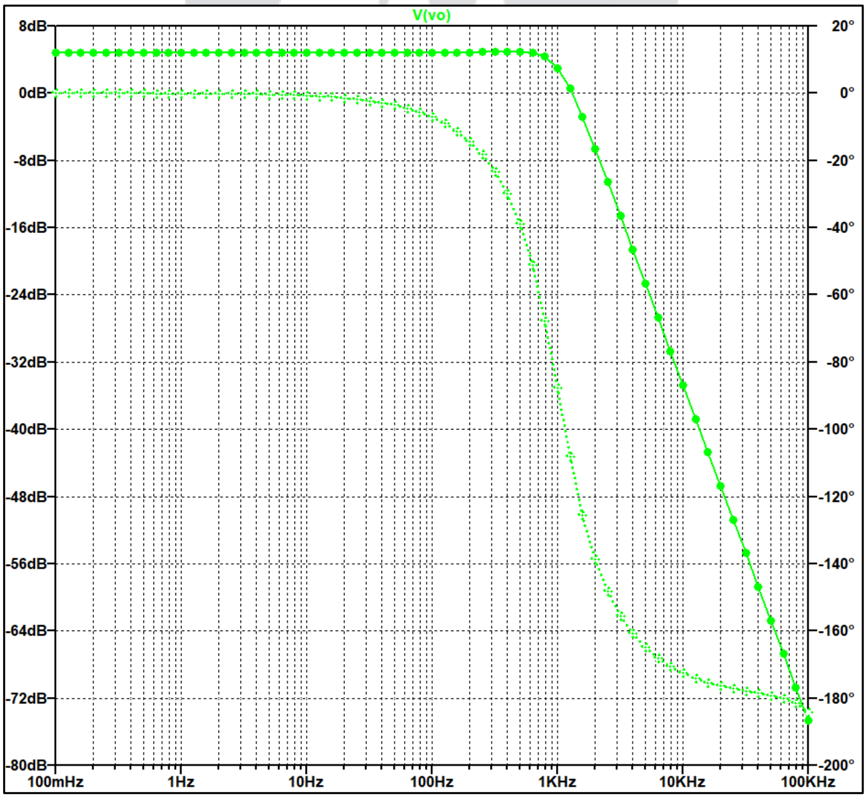

Fig. iv) Frequency Response [Decibel]

Result ↬

The experiment demonstrated the design and frequency response of a second-order low-pass filter. The filter passed signals below the cut-off frequency f_H and attenuated higher frequencies at 40 dB/decade, matching theoretical expectations.

Conclusion ↬

The second-order low-pass filter was designed and tested successfully, matching the expected theoretical and simulation results. The filter exhibited the correct frequency response with the predicted roll-off rate beyond the cut-off frequency.

Precautions ↬

- Ensure all connections are correct and components are securely placed.
- Do not exceed the voltage ratings of components, especially the op-amp.
- Verify capacitor polarity and op-amp orientation.
- Double-check the circuit setup before powering on the equipment.