भारतीय विज्ञान संस्थान
INDIAN INSTITUTE OF SCIENCE

Department of
Electronic
Systems
Engineering

# INDIAN INSTITUTE OF SCIENCE, BENGALURU

# DEPARTMENT OF ELECTRONIC SYSTEMS ENGINEERING

## DESIGN FOR ANALOG CIRCUITS LABORATORY REPORT

ASSIGNMENT 7

ACTIVE FILTERS

SOUMYA KANTA RANA

S.R. No. : 04-01-00-10-51-21-1-19261

September 26, 2021

# Contents

# List of Figures

# 1 Low Pass Filter

## 1.1 Aim

To perform transient and frequency domain simulations of active low pass filter.

## 1.2 Schematic

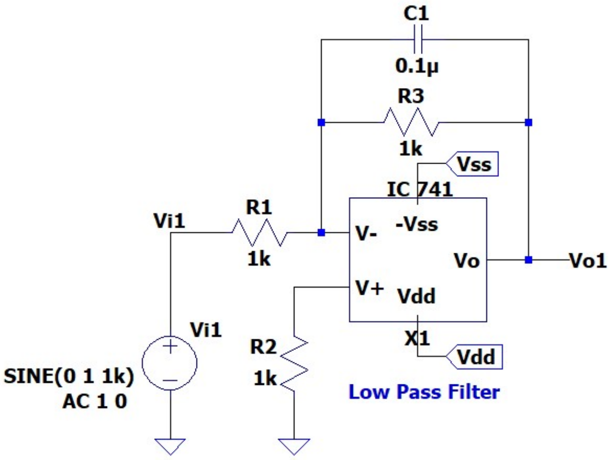


Figure 1: LTSpice Schematic of Low Pass Filter

## 1.3 Component Selection

The transfer function of the filter (assuming ideal op-amp) is given by

$$\frac{V_{o1}(s)}{V_{i1}(s)} = -\frac{R_3}{R_1}\frac{1}{1+sR_3C_1} \tag{1}$$

The -3 dB cutoff frequency of the filter is $f_L = \frac{1}{2\pi R_3 C_1}$.For obtaining a cutoff frequency of 1.59 kHz=10 krad/s, we choose $R_1 = R_2 = R_3 = 1k\Omega$ and $C_1 = 0.1\mu F$.

## 1.4 Frequency Response

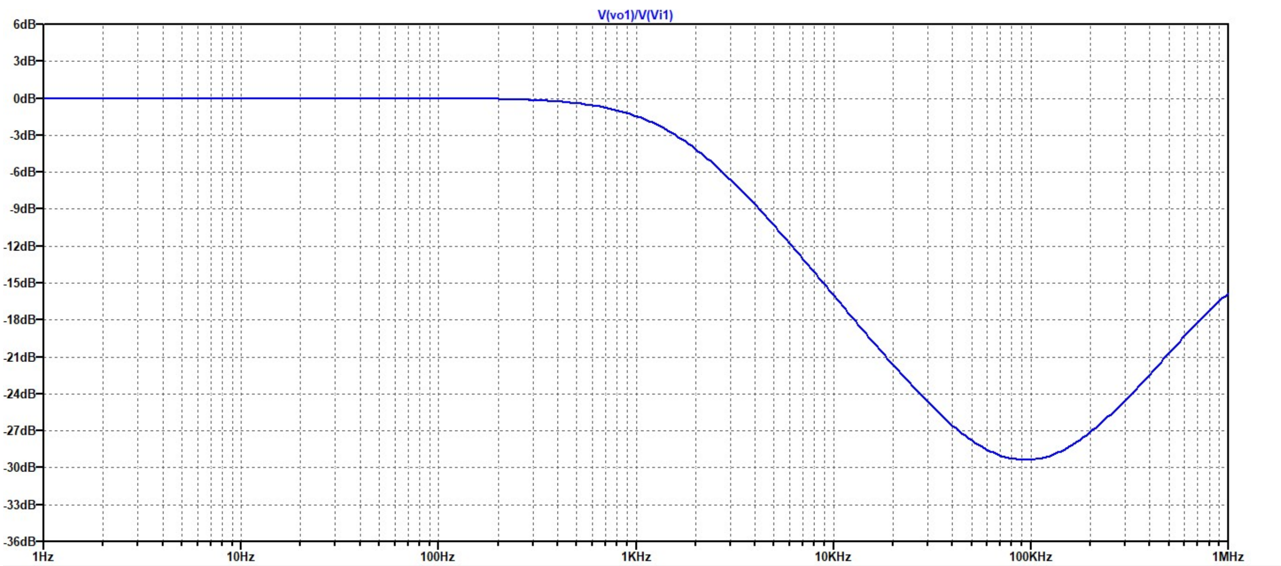


Figure 2: Frequency response of Low Pass Filter

The figure 2 above shows the frequency response of the low pass filter circuit. The -3 dB cutoff frequency obtained is 1589.89 Hz from LTSpice measurement.

## 1.5 Transient Response

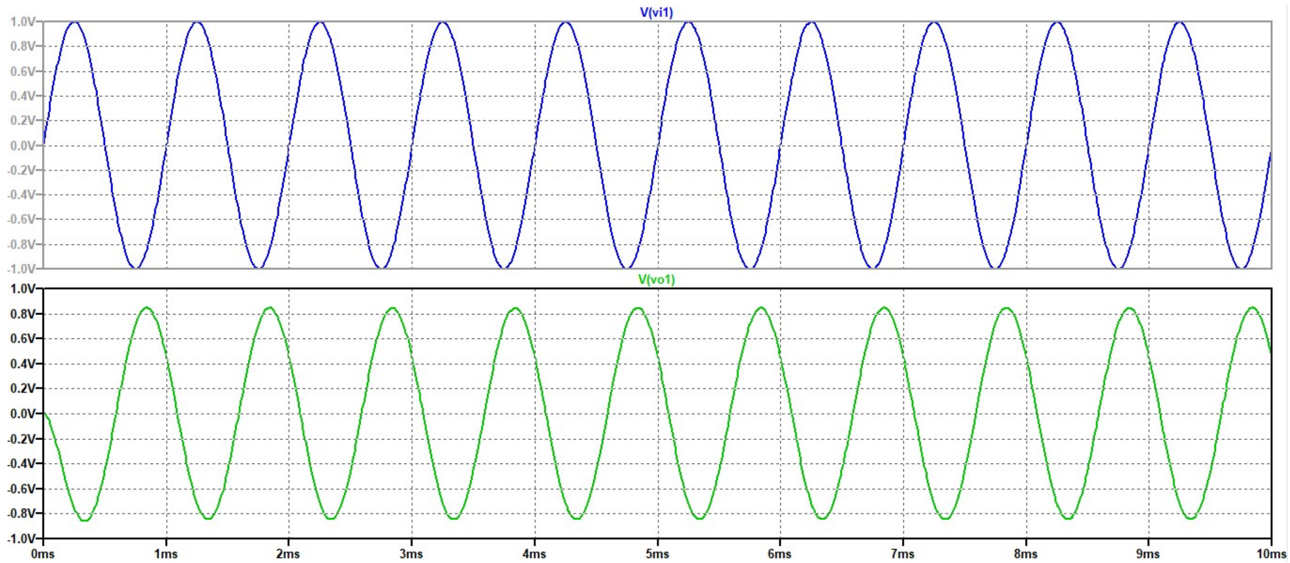


Figure 3: Transient response of Low Pass Filter

The figure 3 above shows the transient simulation results with $1V, 1kHz$ sinewave input. An output voltage of $0.846V$ is obtained.

# 2 High Pass Filter

## 2.1 Aim

To perform transient and frequency domain simulations of active high pass filter.

## 2.2 Schematic

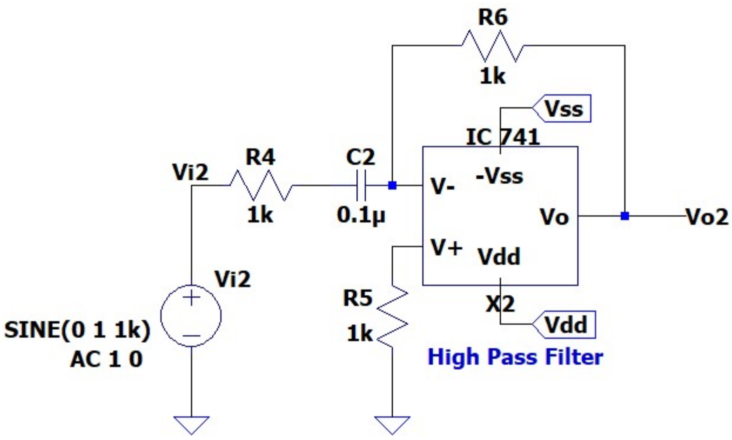


Figure 4: LTSpice Schematic of High Pass Filter

## 2.3 Component Selection

The transfer function of the filter (assuming ideal op-amp) is given by

$$\frac{V_{o2}(s)}{V_{i2}(s)} = -\frac{R_6}{R_4}\frac{sC_2R_4}{1+sC_2R_4} \tag{2}$$

The -3 dB cutoff frequency of the filter is $f_L = \frac{1}{2\pi R_4 C_2}$.For obtaining $f_L = 1.59kHz = 10krad/s$, we choose $R_4 = R_5 = R_6 = 1k\Omega$ and $C_2 = 0.1\mu F$.

## 2.4 Frequency Response

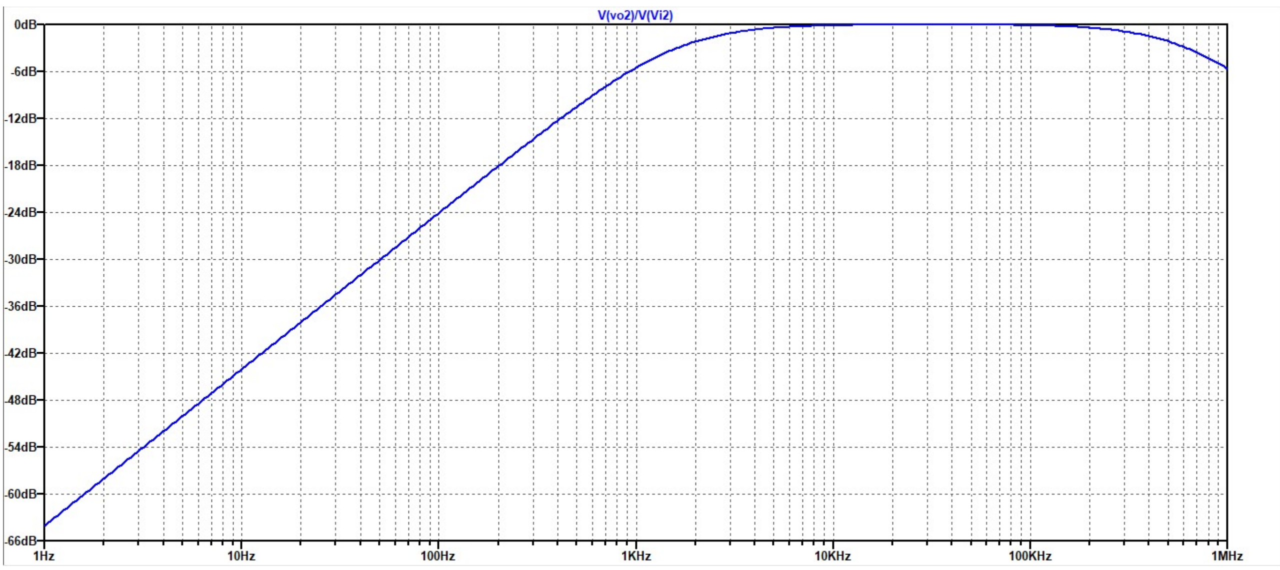


Figure 5: Frequency response of High Pass Filter

The figure 5 above shows the frequency response of the high pass filter circuit. The -3 dB cutoff frequency obtained is 1588.59 Hz.

## 2.5 Transient Response

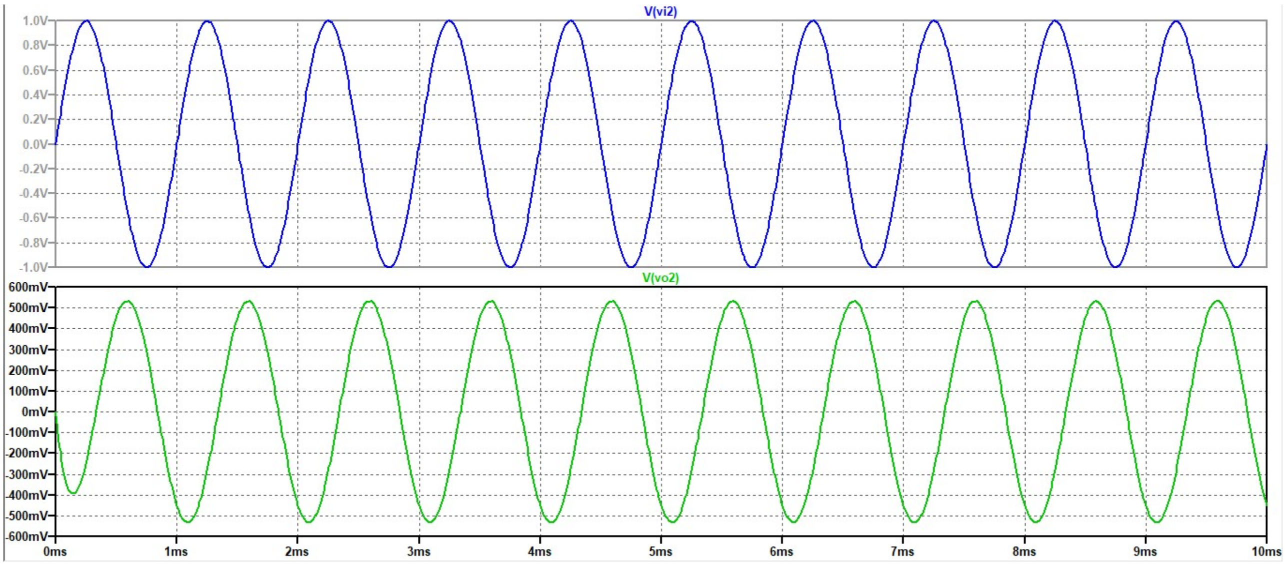


Figure 6: Transient response of High Pass Filter

The figure 6 above shows the transient simulation results with $1V, 1kHz$ sinewave input. An output voltage of $0.532V$ is obtained.

# 3 Band Pass Filter

## 3.1 Aim

To perform transient and frequency domain simulations of active band pass filter.

## 3.2 Schematic

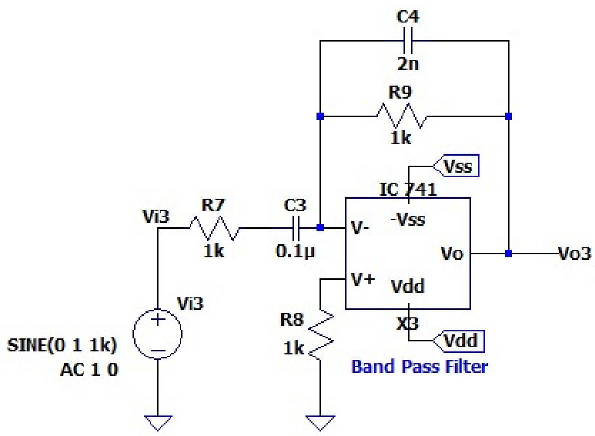


Figure 7: LTSpice Schematic of Band Pass Filter

## 3.3 Component Selection

The transfer function of the filter circuit (assuming ideal op-amp) is given by

$$\frac{V_{o3}(s)}{V_{i3}(s)} = -\frac{R_9}{R_7}\frac{1}{1+sR_9C_4}\frac{sC_3R_7}{1+sC_3R_7} \tag{3}$$

The -3 dB cutoff frequencies of the filter are $f_H = \frac{1}{2\pi R_9 C_4}$ and $f_L = \frac{1}{2\pi R_7 C_3}$, $f_L$ and $f_H$ being the lower and upper cuttoff frequencies respectively.For obtaining $f_L = 1.59kHz = 10krad/s$ and $f_H = 80kHz = 502.7krad/s$, we choose $R_7 = R_8 = R_9 = 1k\Omega$ ,$C_3 = 0.1\mu F$ and $C_4 = 2nF$.

## 3.4 Frequency Response

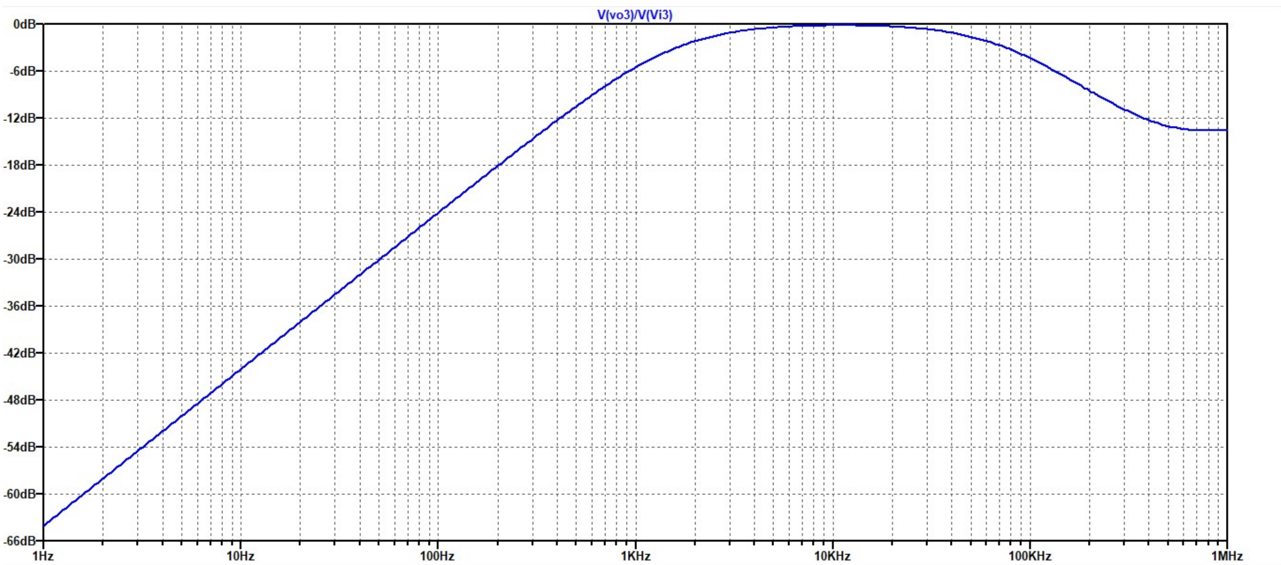


Figure 8: Frequency response of Band Pass Filter

The figure 8 above shows the frequency response of the band pass filter circuit. The -3 dB cutoff frequencies obtained are 1589.25 Hz and 75.393 kHz respectively.

## 3.5 Transient Response

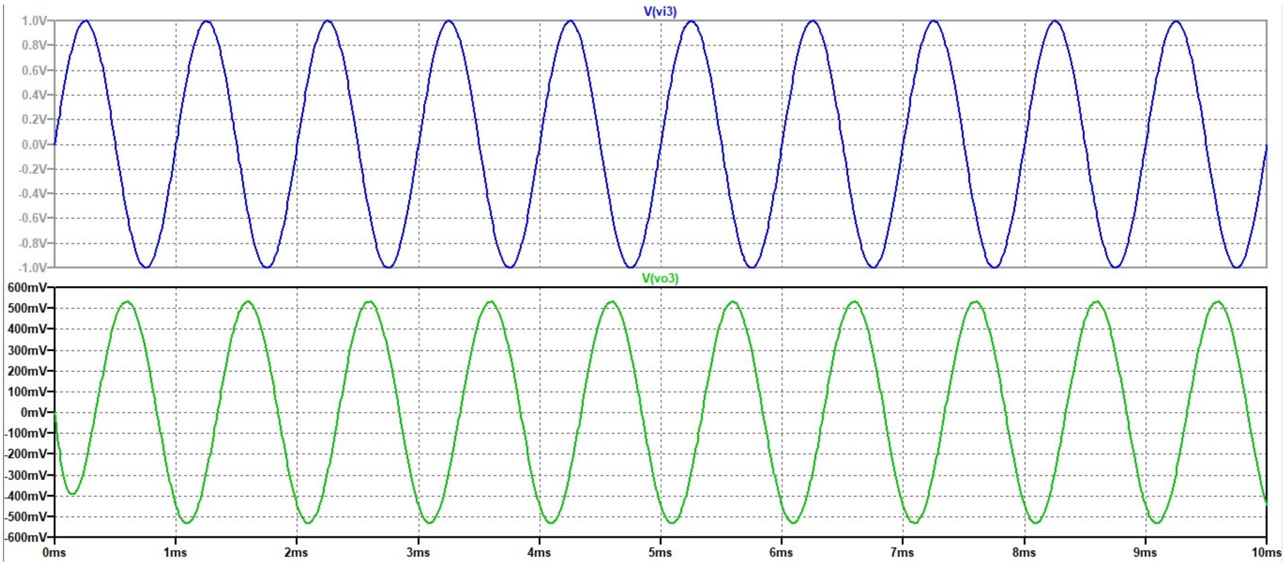


Figure 9: Transient response of Band Pass Filter

The figure 9 above shows the transient simulation results with $1V, 1kHz$ sinewave input. An output voltage of $0.532V$ is obtained.

# 4 Band Reject Filter

## 4.1 Aim

To perform transient and frequency domain simulations of active band reject filter.

## 4.2 Schematic

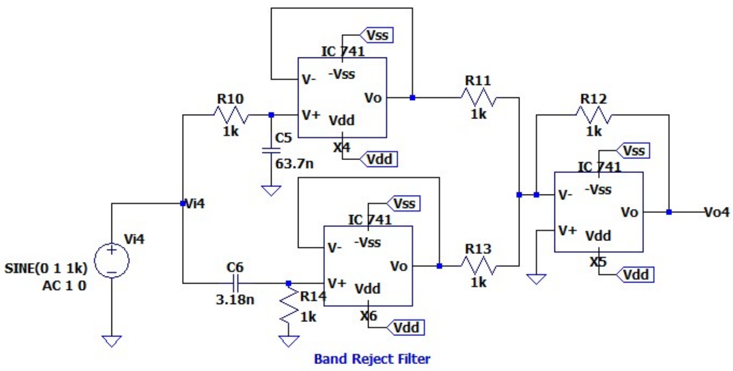


Figure 10: LTSpice Schematic of Band Reject Filter

## 4.3 Component Selection

The transfer function of the filter (assuming ideal op-amp and $R_{11} = R_{13}$) is given by

$$\frac{V_{o4}(s)}{V_{i4}(s)} = -\frac{R_{12}}{R_{11}}\left(\frac{1}{1+sR_{10}C_5} + \frac{sR_{14}C_6}{1+sR_{14}C_6}\right) \tag{4}$$

The -3 dB cutoff frequencies of the filter are $f_H = \frac{1}{2\pi R_14C_6}$ and $f_L = \frac{1}{2\pi R_{10}C_5}$, $f_L$ and $f_H$ being the lower and upper cuttoff frequencies respectively.For obtaining $f_L = 2.5kHz = 15.71krad/s$ and $f_H = 50kHz = 314.16krad/s$, we choose $R_{10} = R_{11} = R_{12} = R_{13} = R_{14} = 1k\Omega$ ,$C_5 = 63.7nF$ and $C_6 = 3.18nF$.

## 4.4 Frequency Response

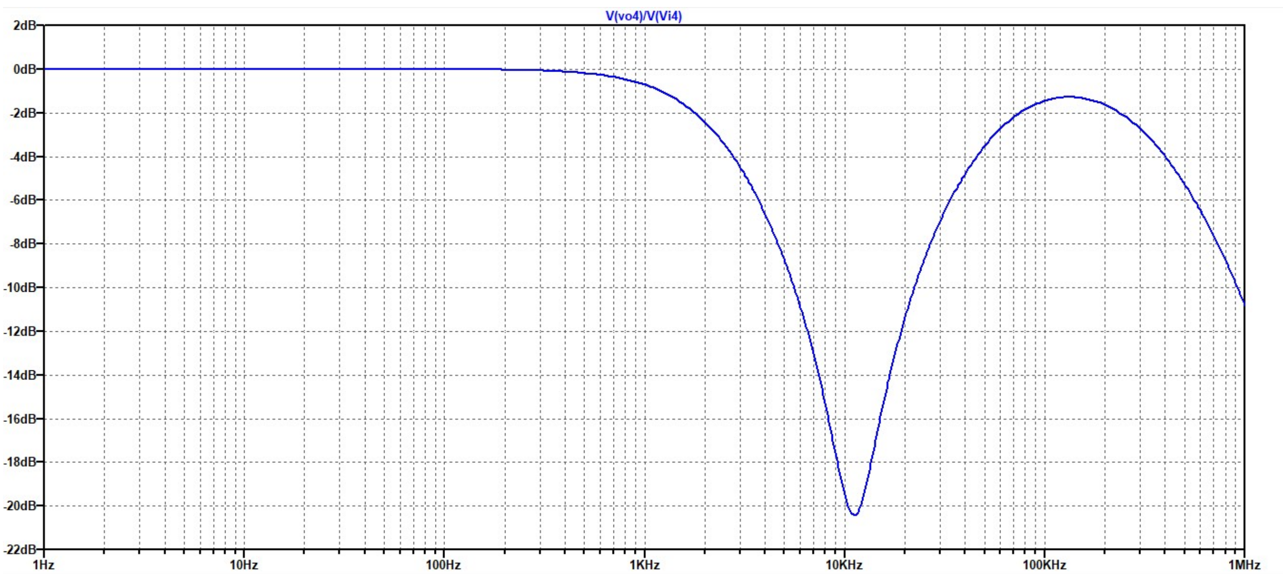


Figure 11: Frequency response of Band Reject Filter

The figure 11 above shows the frequency response of the band reject filter circuit. The -3 dB cutoff frequencies obtained are 2289.85 Hz and 55.823 kHz respectively.

## 4.5 Transient Response

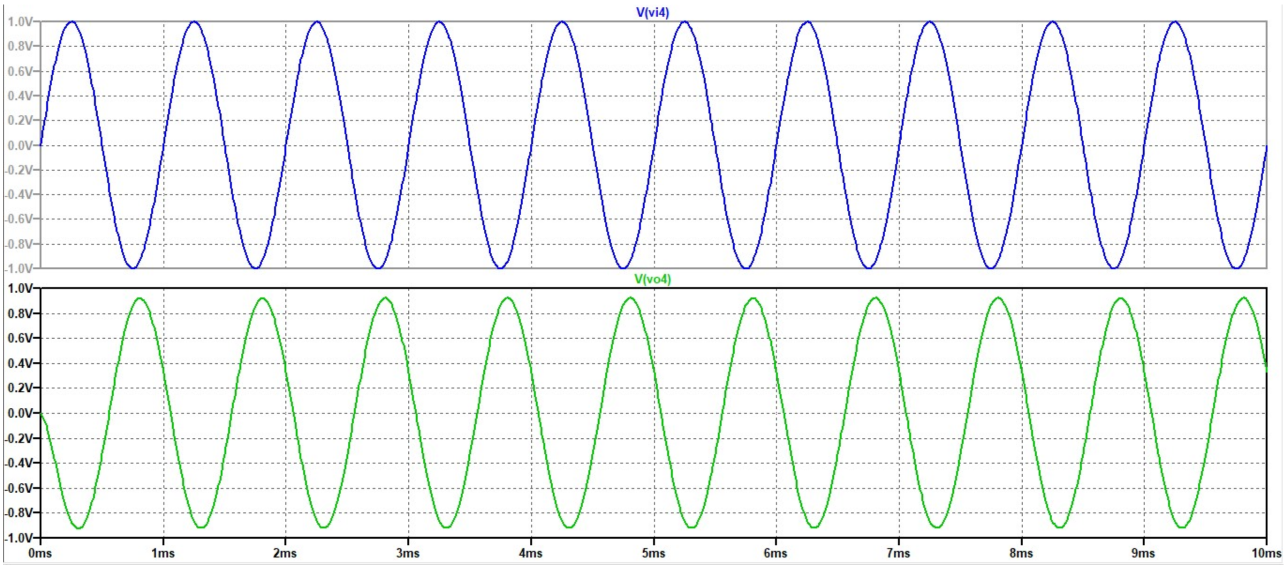


Figure 12: Transient response of Band Reject Filter

The figure 12 above shows the transient simulation results with $1V, 1kHz$ sinewave input. An output voltage of $0.922V$ is obtained.

# 5 Conclusion

a The op-amp is a vital component of active filters. As a result, the performance of the filter depends largely on the op-amp parameters. Due to high frequency limitations of the op-amp the high-frequency response obtained is often not desirable (as evident from figures 5 and 11 respectively). The IC741 op-amp having an unity gain bandwidth of 1 MHz, its gain at frequencies higher than 10kHz is not good enough for the ideal op-amp approximations used to derive the transfer functions.

b A very important advantage of active filters is that it can provide gain to the output signal, which is not possible with passive filters.

c The active filter also eliminates usage of inductors, reducing the weight and footprint of the circuit.

d Due to the high frequency limitations active filters cannot be used in RF applications. Also, the input and output voltage range is limited by the op-amp supply voltage levels.