1 GHz Inverse Filters using Operational Amplifier

Bharath Kumara[1], Palak Goel[2], Pallavi Sharma[3]

[1]Asst. Professor, Dept. of ECE, M S Ramaiah University of Applied Sciences, Bangalore, Karnataka, India
[2]B.E Student, Dept. of ECE, M S Ramaiah University of Applied Sciences, Bangalore, Karnataka, India
[3] B.E Student, Dept. of ECE, M S Ramaiah University of Applied Sciences, Bangalore, Karnataka, India

---***---

Abstract - *1 GHz first and second order operational amplifier based inverse filters are introduced. Low pass- 1st order inverse filters, high pass- 1st order inverse filters and bandpass- 2nd order inverse filter circuits are introduced. The filters presented are also verified using SPICE simulator.*

Key Words: Operational amplifier, low pass filter, high pass filter, biquad band pass filter.

1. INTRODUCTION

The unwanted distortions present in a processing system or a transmission system are demolished by the use of inverse filters. The application areas of inverse filters thus include instrumentation, control and communication systems.

The non- inverting op- amp configuration is used to design the inverse filter discussed in section II. The op- amp based first order low pass and high pass filters are discussed in section III. Section IV has the description of inverse band pass biquad filter using op-amp.

2. NON- INVERTING OP- AMP CONFIGURATION

The inverting op amp configuration is used in numerous applications, popularly including oscillator circuits, scaling summer amplifiers, balanced amplifier etc, whereas the non inverting op- amp configuration do not have much applications in the same domain. However, the use of non- inverting op- amp configuration is presented in this section.
The general non- inverting operational amplifier circuit is depicted in fig 1.

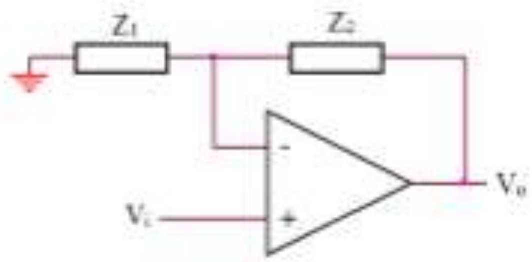

Fig -1: Non-inverting op-amp configuration used for realization of filter

The voltage mode transfer function of this configuration can be represented as:

$$\frac{V_o}{V_i} = 1 + \frac{Z_1}{Z_2} \qquad (1)$$

3. FIRST ORDER INVERSE OP AMP FILTERS

Operational amplifier first order inverse filter has been presented in this section. Inverse high pass and inverse low pass filters (IHPF and ILPF) circuits are realised with the help of different impedance values.

First order ILPF and IHPF transfer functions with cut –off frequency, ω_c are shown:

$$H_{ILPF}(s) = \frac{(s+\omega_c)}{\omega_c} \qquad (2a)$$

$H_{IHPF}(s) = \frac{(s+\omega_C)}{s}$ __________(2a)

3.1 First order inverse low –pass filter circuits

The first order op- amp inverse low pass filter circuit is show in the figures 2(a) and 2(b). The gain for the circuit presented in fig 2(a) given by:

$\frac{V_O}{V_i} = (1 + sCR) = \frac{s+\frac{1}{CR}}{\frac{1}{CR}}$ ____(3a)

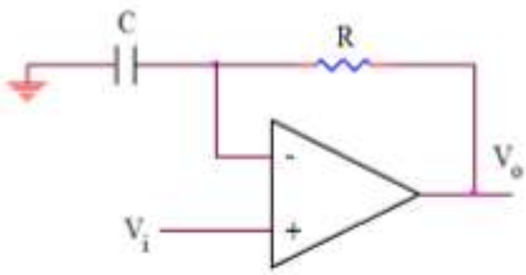

Fig- 2(a)

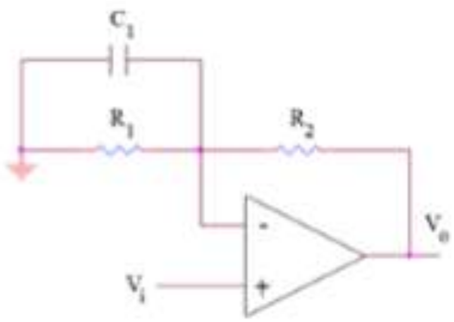

Fig- 2(b)

Fig. 2 (a)-2(b): First order inverse low-pass filter circuits using op-amp

Similarly the transfer function of inverse op- amp shown in figure 2(b) can be represented by;

$\frac{V_O}{V_i} = 1 + \frac{R_2}{R_1}\frac{[s+\frac{1}{C_1}(\frac{1}{R_1}+\frac{1}{R_2})]}{\frac{1}{C_1}(\frac{1}{R_1}+\frac{1}{R_2})}$ ______________(3b)

The first order op- amp Inverse low pass filters depicted in figures 2(a) and 2(b) have DC gains equal to 1 and 6 respectively.

3.2 First order inverse high –pass filter circuits

The gain functions of first order inverse high pass filter depicted in fig 3(a) is represented by the equation:

$\frac{V_O}{V_i} = \frac{s+\frac{1}{CR}}{s}$ ____________(4a)

The first order inverse low pass filter design (fig 3a) is obtained by slightly modifying the ILPF design in fig 2(a). The modification is done by interchanging the R and C components.

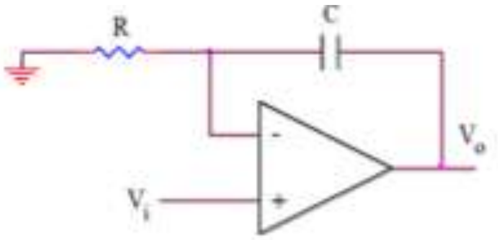

Fig- 3(a)

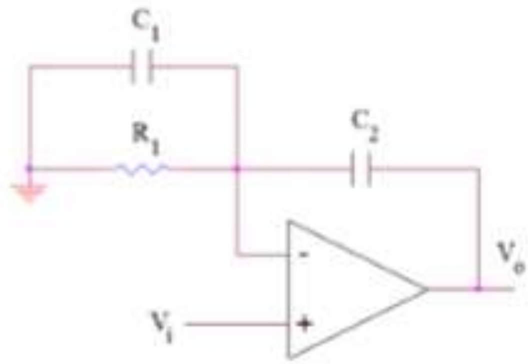

Fig- 3(b)

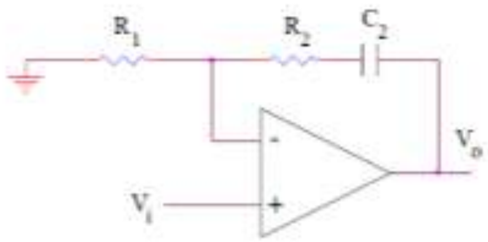

Fig- 3(c)

Fig. 3 (a)-(c): First order inverse high-pass filter using op-amp

The transfer function of the gain of the IHPF shown in the figure 3(b) is given by;

$$\frac{V_o}{V_i} = \left(1 + \frac{C_1}{C_2}\right) \frac{\left(s + \frac{1}{R_1(C_1+C_2)}\right)}{s} \qquad (4b)$$

The transfer function of the gain of the IHPF shown in figure 3(c) is given as;

$$\frac{Vo}{Vi} = \left(1+\frac{R_2}{R_1}\right) \frac{\left(s+\frac{1}{(R_1+R_2)C_2}\right)}{s} \qquad (4c)$$

4. INVERSE BAND PASS BIQUAD FILTER USING OP-AMP

I. INVERSE BAND PASS BIQUAD FILTER USING OP-AMP

The inverse second- order band pass filter with the help of an op- amp is simulated and shown in the figure (5);

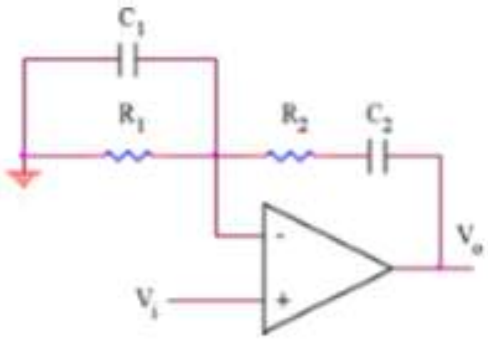

Fig- 5 Inverse band-pass biquad using op-amp

The gain transfer function for the filter shown above is given by:

$$\frac{Vo}{Vi} = \frac{\left(1+\frac{R_2}{R_1}+\frac{C_1}{C_2}\right)\left\{s^2 + s\left(\frac{1}{R_1C_1}+\frac{1}{R_2C_1}+\frac{1}{R_2C_2}\right)+\frac{1}{R_1C_1R_2C_2}\right\}}{s\left(\frac{1}{R_1C_1}+\frac{1}{R_2C_1}+\frac{1}{R_2C_2}\right)} \quad (5)$$

5. SIMULATION RESULTS

A voltage controlled voltage source (VCVS) is used to simulate the filters presented in this document. Performance parameters including open-loop voltage gain, input impedance and output impedance. Various parameters and their values used in the simulation are given in the table (1).

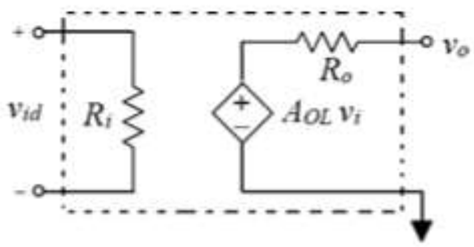

Fig- 6 Two-port VCVS model of op-amp

Table-1: Simulation details

Op-amp model used	VCVS
Input resistance	R_i= 200 kΩ
Output resistance	R_o=75 Ω
open loop differential amplifier-Voltage gain	A_{OL}=2*10^5
Simulator used	SPICE

Fig (7) shows the transfer function plot of the first order inverse low pass filter. The ILPF is designed for cut-off frequency, ω_c = 1 GHz. The resistance and capacitance values used are 159.154 MΩ and 1pF respectively.

Fig (8) shows the transfer function plot of the first order inverse high pass filter. The IHPF is designed for cut-off frequency, ω_c = 1 GHz. The resistance and capacitance values used are 159.154 MΩ and 1pF respectively.

The second order inverse band pass biquad filter depicted in the figure (5) designed for a centre frequency of 1 GHz by selecting R_1 and R_2 = 159.154 MΩ and C_1 and C_2 = 1 pF is simulated and the transfer function response plot is plotted is shown in fig (9).

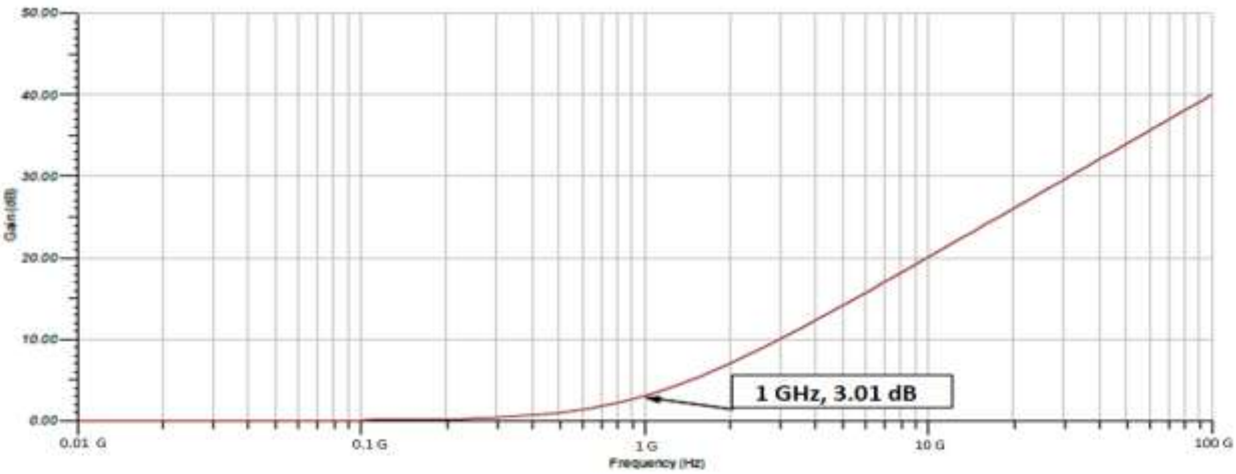

Fig- 7: Amplitude response of first order inverse low-pass filter using op amp given in Fig. 2(a)

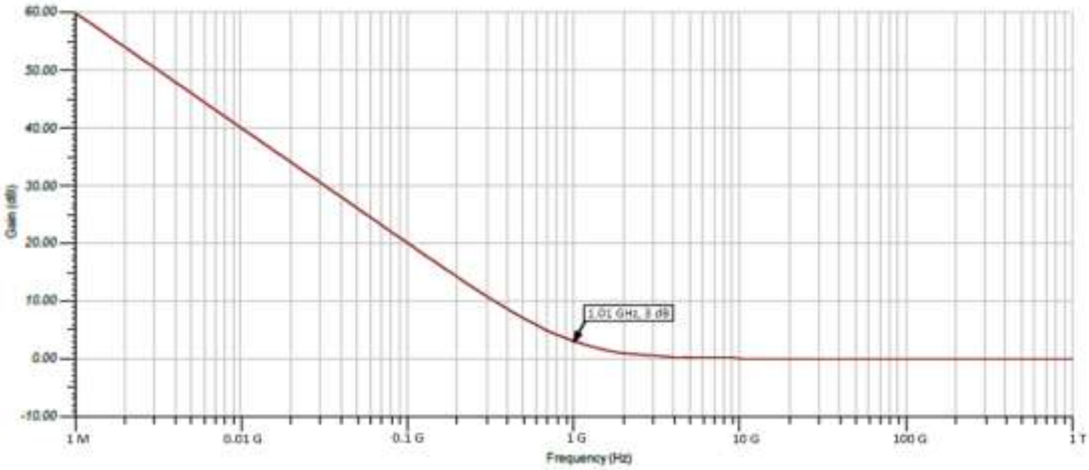

Fig- 8: Amplitude response of first order inverse high-pass filter using op amp given in Fig. 3(a)

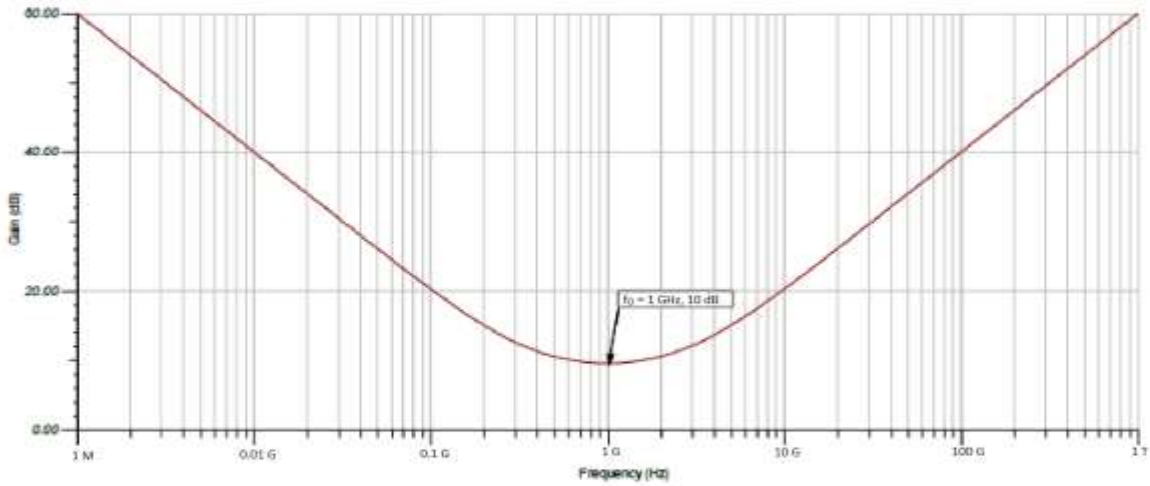

Fig- 9: Amplitude response of inverse biquad band-pass filter using op- amp given in Fig. 5

6. CONCLUSIONS

A first- order inverse low pass filter, a first- order inverse high pass filter and a first- order inverse biquad filter using op- amps in non- inverting configuration are presented in this paper. The proposed inverse filter circuits are verified with the help of simulations in SPICE tool.

REFERENCES

[1] Tsukutani, T., Kunugasa, Y. and Yabuki, N., "CCII-Based Inverse Active Filters with Grounded Passive Components," Journal of Electrical Engineering, vol. 6, pp. 212-215, 2018.

[2] Shah, N. A. and Rather, M. F., "Realization of voltage-mode CCII-based all-pass filter and its inverse version," Indian Journal of Pure and Applied Physics, vol. 44, pp. 269-271, March 2006.

[3] Gupta, S. S., Bhaskar, D. R., Senani, R. and Singh, A. K., "Inverse active filters employing CFOAs," Electrical Engineering, vol. 91, no. 1, pp. 23- 26, 2009.

[4] Vishal Patil, R K Sharma, "Novel Inverse Active Filters Employing CFOAs," International Journal for Scientific Research & Development (IJSRD), vol. 3, no. 07, pp. 359-360, 2015.

[5] Hung-Yu Wang, Sheng-Hsiung Chang, Tzu-Yi Yang, Po-Yang Tsai, "A novel multifunction CFOA-based inverse filter," Circuits and Systems, vol. 2, pp. 14-17, 2011.

[6] Dattaguru V. Kamath, "OTA-C Transimpedance Biquads derived from Passive Filters," International Journal of Technical Research and Applications (IJTRA), Special Issue 23, pp. 6-12, June, 2015.

[7] Dattaguru V. Kamath, "Overview of Opamp and OTA based Integrators," International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE), vol. 3, no. 9, pp. 74-81, Sept. 2015.

[8] Tsukutani, Takao, Yasuaki Sumi, and Noboru Yabuki, "Electronically tunable inverse active filters employing OTAs and grounded capacitors," International Journal of Electronics Letters, vol. 4, no. 2, pp. 166-176, 2016.

[9] Dattaguru V. Kamat, P. V. Ananda Mohan and K. Gopalakrishna Prabhu, "Novel First-order and Second-Order Current-mode filters using Dual- output OTAs and Grounded Capacitors," IEEE Asia Pacific Region 10 (TENCON) Conference held at Hyderabad, India, IEEEXplore, pp. 1-6, 19-21, Nov. 2008.

[10] Dattaguru V. Kamath, P. V. Anandamohan and K. Gopalkrishna Prabhu, "Novel first order and second order current-mode filters using multiple output operational transconsuctance amplifiers," Circuits, Systems, and Signal Processing, Birkhäuser Boston Publishers, vol. 29, no. 3, pp. 553- 576, June 2010.

[11] D. V. Kamat, "OTA based current-mode first order and second order amplitude equalizer," International Journal of Electrical, Electronics and Data Communication (IJEEDC), vol. 7, no. 1, pp. 57-60, Jan. 2019.

[12] Dattaguru V Kamat, Ananda Mohan P V, K. Gopalkrishna Prabhu, "OTA- based current-mode filter and oscillator," US Patent No. 8659363, 2014.

BIOGRAPHIES

"Mr. Bharath Kumara, B.E in ECE, M.Tech in DECS, PGDHRM, E-MBA, pursuing Ph.D, in ECE at VTU, Belgaum. Currently working as an Assistant Professor in the dept. of ECE, MSRUAS, Bangalore. Many papers are published in standard international journals in the research area of Wireless sensor networks. Life member of ISTE, Delhi.

"Miss. Palak Goel, presently pursuing B.E in Electronics and Communication Engineering (third year) from MSRUAS, Bangalore''.

"Miss. Pallavi Sharma, presently pursuing B.E in Electronics and Communication Engineering (third year) from MSRUAS, Bangalore''