1 GHz Inverse Filters using Operational Amplifier

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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:

\[ \frac{V_o}{V_i} = 1 + \frac{Z_1}{Z_2} \quad (1) \]

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, \( \omega_c \) are shown:

\[ H_{ILPF}(s) = \frac{(s+\omega_c)}{\omega_c} \quad (2a) \]
H_{ILPF}(s) = \frac{s + \alpha C}{s} \quad (2a)

3.1 First order inverse low-pass filter circuits

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

\[
\frac{V_o}{V_i} = (1 + sCR) = \frac{s + 1}{CR} \quad (3a)
\]

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

\[
\frac{V_o}{V_i} = 1 + \frac{R_2}{R_1} \left[ s + \frac{1}{RC} \left( \frac{1}{R_1} + \frac{1}{R_2} \right) \right] \quad (3b)
\]

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:

\[
\frac{V_o}{V_i} = \frac{s + \frac{1}{CR}}{s} \quad (4a)
\]

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:

\[
\frac{V_o}{V_i} = \left(1 + \frac{C_1}{C_2}\right) \frac{\left(\frac{1}{R_1(C_1+C_2)}\right)}{s} \quad (4b)
\]

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

\[
\frac{V_o}{V_i} = \left(1 + \frac{R_2}{R_1}\right) \frac{\left(\frac{1}{(R_1+R_2)C_2}\right)}{s} \quad (4c)
\]

**4. INVERSE BAND PASS BIQUEAD FILTER USING OP-AMP**

**I. INVERSE BAND PASS BIQUEAD 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);
The gain transfer function for the filter shown above is given by:

\[
\frac{v_o}{v_i} = \frac{(1 + \frac{1}{R_1 C_1}) s^2 + \frac{1}{R_1 C_1} + \frac{1}{R_2 C_2} \left( \frac{1}{R_1 C_1} + \frac{1}{R_2 C_2} \right)}{s \left( \frac{1}{R_1 C_1} + \frac{1}{R_2 C_2} \right)} \quad (5)
\]

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).

![Two-port VCVS model of op-amp](image)

### Table-1: Simulation details

<table>
<thead>
<tr>
<th>Op-amp model used</th>
<th>VCVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input resistance</td>
<td>( R_i = 200 \text{ k\Omega} )</td>
</tr>
<tr>
<td>Output resistance</td>
<td>( R_o = 75 \text{ \Omega} )</td>
</tr>
<tr>
<td>open loop differential amplifier-Voltage gain</td>
<td>( A_{OL} = 2 \times 10^5 )</td>
</tr>
<tr>
<td>Simulator used</td>
<td>SPICE</td>
</tr>
</tbody>
</table>

Fig (7) shows the transfer function plot of the first order inverse low pass filter. The ILPF is designed for cut-off frequency, \( \omega_c = 1 \text{ GHz} \). The resistance and capacitance values used are 159.154 M\Omega 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, \( \omega_c = 1 \text{ GHz} \). The resistance and capacitance values used are 159.154 M\Omega 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 \( R_2 = 159.154 \text{ M\Omega} \) and \( C_1 \) and \( C_2 = 1 \text{ pF} \) 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


BIOGRAPHIES

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