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Inductor Simulation using Operational Transresistance Amplifier and its Application

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Abstract—*This paper proposes simulation of a grounded inductor using Operational Transresistance Amplifiers that can replace an actual inductor. The inductance value can be varied by varying the resistance or the capacitance of passive components. The passive components used are virtually grounded. An application of the simulated inductor has been discussed in order to show its compatibility with more complex circuits. PSPICE simulations have been performed to ensure the workability of the circuits. All simulation results have been provided.*

1. INTRODUCTION

An inductor can be used in analog signal processing for making various useful applications like filters, oscillators etc owing to its simple yet powerful frequency characteristics. But due to its bulky design, it rarely used directly in circuits. Various authors have proposed ways to simulate inductors using an active device along with passive components like resistors and capacitors[1-5]. This simulated inductor can then easily be used in circuits to obtain more complex transfer functions (for example, see applications shown in in [1, 3, 4]).

In [3], the author has proposed two ways to realize grounded inductors using two OTRAs and six passive components in each. The resistive components, however, must satisfy a condition to realize a grounded inductor. In [4], the author has used OTRA to realize positive or negative inductance in parallel with positive or negative resistance under different conditions.

In this paper, we have proposed a new way to realize a grounded inductor using two Operational Transresistance Amplifiers and a few passive components. Unlike the proposed circuit in [3], the passive components used in the simulated inductor do not require to fulfill any such condition in terms of resistive components. Ideally, the circuit does not show any resistive value and thus it acts as a pure inductor unlike the circuits proposed in [4]. In order to ensure the workability of our proposed design, we have designed a RLC band pass filter circuit using the simulated inductor as an application of the proposed circuit.

The next section gives a brief introduction to OTRA. The proposed circuit of grounded inductor as well as the band pass filter circuit is given in section 3 along with the required expressions for their tunability. All simulation results are given in section 4. Section 5 gives the concluding remarks.

2. OTRA - AN INTRODUCTION

Operational Transresistance Amplifier (OTRA) is an active device that provides high transresistance gain to the input differential current [6]. Ideally, the transresistance gain is infinity and the inverting as well as the non inverting input currents are equal. Also, both input terminals are virtual grounds. The device symbol is shown in Fig. 1.

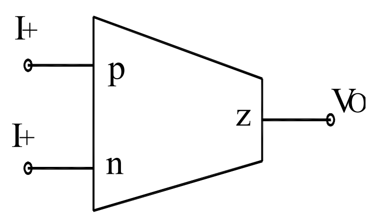

Fig. 1: Symbol of OTRA

The device is characterized by equations given in (1), which also gives the input output relationship. V_+ and V_- are the input terminal potentials corresponding to input currents I_+ and I_- where as V_o is the output terminal potential. R_m is the the transresistance gain.

$$\begin{bmatrix} V_+ \\ V_- \\ V_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ R_m & -R_m & 0 \end{bmatrix} \begin{bmatrix} I_+ \\ I_- \\ I_o \end{bmatrix} \quad (1)$$

The equations contained in (1) can be written individually as shown in (2).

$$V_+ = V_- = 0 \quad \& \quad V_o = R_m(I_+ - I_-) \qquad (2)$$

Ideally, $R_m \to \infty$. Thus, $I_+ = I_-$

OTRA can be implemented using two Current Feedback Operational Amplifiers (CFOAs) (see [5] and the references cited therein). Such a realization is shown in Fig. 2. It may also be designed using CMOS technology for VLSI implementation as shown by authors in [6,7]. The implementation of OTRA given by author in [7] is shown in Fig. 3.

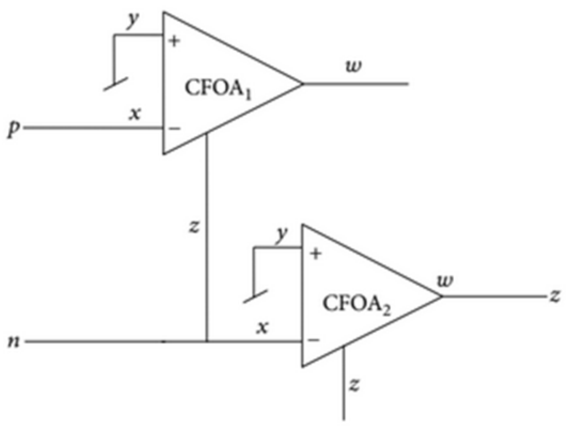

Fig. 2: OTRA implementation using CFOAs

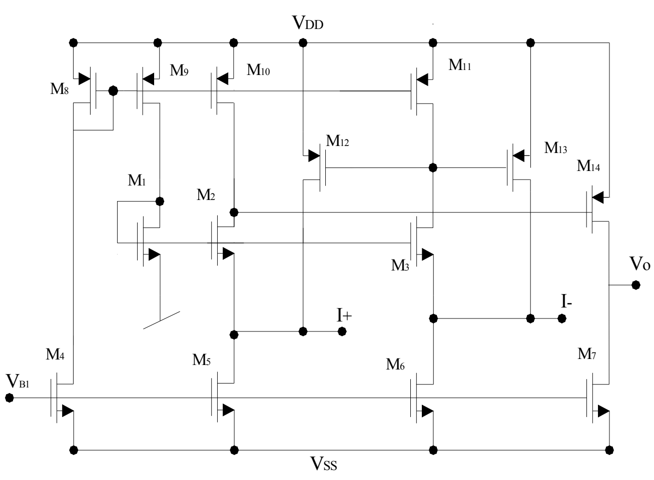

Fig. 3: OTRA implementation using CMOS technology

3. PROPOSED CIRCUITS

In this paper, we propose simulation of a grounded inductor using OTRA as the active building block. The configuration is shown in Fig. 4 where two OTRAs along with a few passive components are used to realize a circuit that has the same input impedance as that of a grounded inductor. The expression for input impedance of the circuit is given by (3) which can be derived using the equations given in (1).

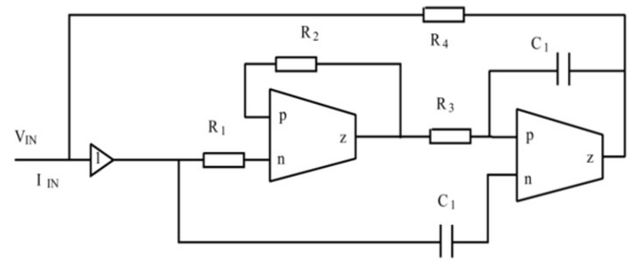

Fig. 4: Simulation of grounded inductor using OTRA

$$\mathrm{Zin} = \frac{sC_1R_1R_3R_4}{R_2} \qquad (3)$$

Impedance of an inductor is sL, where L is the inductance. Thus, the simulated inductance is found to be:

$$L = \frac{C_1R_1R_3R_4}{R_2} \qquad (4)$$

Hence varying the resistance and capacitance values of resistors and capacitors can vary the inductance in accordance with (4)

An electrical filter is one of the important applications of an inductor. In order to ensure the workability of our design and its compatibility with filters, we have designed a 2nd order RLC band pass filter circuit using the proposed simulated inductor instead of an actual one. Fig. 5 shows the RLC band pass filter circuit with an actual inductor whereas Fig. 6 shows an equivalent circuit where a simulated inductor is used. The transfer function of the filter is given by (5). The center frequency as well as the bandwidth expressions are given by (6) and (7) respectively.

$$\frac{V_o}{V_{in}} = \frac{S\left(\frac{1}{C_0R_0}\right)}{S^2 + s\left(\frac{1}{C_0R_0}\right) + \left(\frac{1}{L_0C_0}\right)} \qquad (5)$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad (6)$$

$$\frac{\omega_o}{Q} = \frac{1}{C_0R_0} \qquad (7)$$

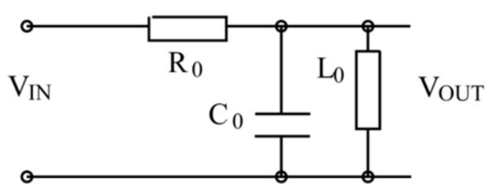

Fig. 5: RLC band pass filter circuit

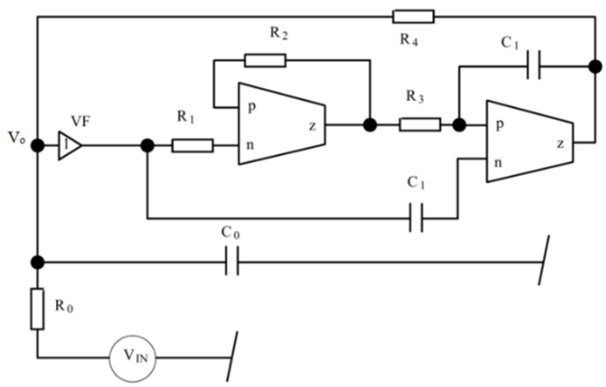

Fig. 6: RLC band pass filter circuit using simulated inductor

4. SIMULATION RESULTS

For simulation purposes, OTRA was designed using CFOAs as shown in Figure2 with ±12V power supply. The values of passive components used for simulation of inductance are: C_1 = 0.2nF and $R_1 = R_2 = R_3 = R_4$ = 7KΩ. The inductance value for the simulated inductor using (4) and the above values is 9.8mH. The circuit was tested for the frequency response of input impedance. Fig. 7 shows the variation of input impedance with frequency. Any deviations from the theoretical response are due to the non idealities in the circuit.

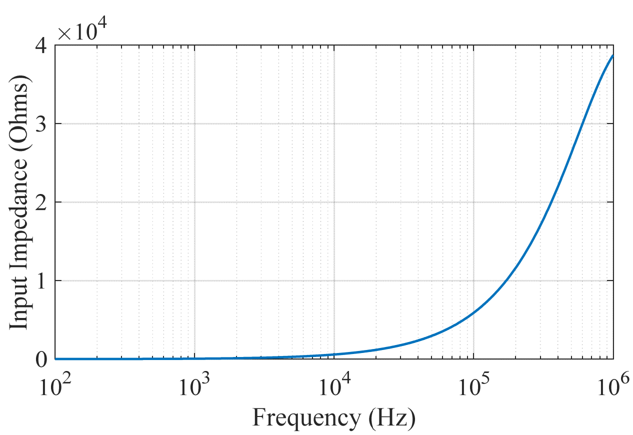

Fig. 7: Variation of input impedance of simulated inductor with frequency

The band pass filter circuit shown in Fig. 6 was also tested for the frequency response which is shown in Fig. 8. The values of passive components used in design of simulated inductor were kept the same as previous case (which gives value of simulated inductance, L_0 = 9.8mH). The values of R_0 and C_0 were chosen to be 14KΩ and 12.5pF respectively. Using these values, the value of center frequency for the band pass filter comes out to be 454.7 KHz for the ideal case. As shown by the frequency response, the center frequency for band pass filter using simulated inductor is close to the ideal value.

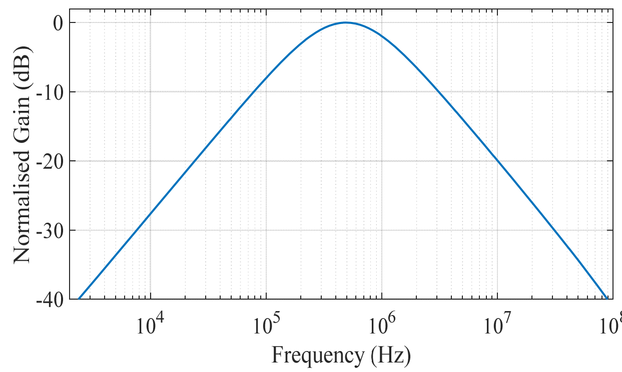

Fig. 8: Band pass filter respone of RLC filter circuit using simulated Inductor

5. CONCLUSION

This paper proposes a new configuration to realize a grounded inductor using Operational Transresistance Amplifiers. The inductance is variable and can be varied by varying the values of passive components. An application (band pass filter) of the simulated inductor is made which shows that the proposed circuit can replace an actual inductor for various circuit designs. PSPICE simulations show that the experimental results are in agreement with theoretical results.

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