A Novel Inductor Simulation Using the Pole of the Operational Amplifier

Eine neue Induktivitätssimulation mit Hilfe der Eigenfrequenz des Operationsverstärkers

By Ahmed M. Soliman

A Report from the Faculty of Engineering, CAIRO UNIVERSITY, Giza-Egypt

Abstract:

A new simple realization of a nonideal grounded inductor is given. The network requires a single operational amplifier and three resistors. The quality factor is controlled by varying a single resistor. Sensitivities to all passive and active circuit components are very low. Modification of the circuit to realize a nonideal floating inductor is illustrated.

Übersicht:

Es wird eine einfache Realisierung einer geerdeten, verlustbehafteten Induktivität angegeben. Die Schaltung benötigt einen Operationsverstärker und drei Widerstände, von denen einer den Gütefaktor bestimmt. Die Empfindlichkeiten bezüglich aller passiven und aktiven Elemente sind sehr gering. Weiter wird eine Modifikation zur Realisierung einer schwebenden, verlustbehafteten Induktivität vorgeschlagen.

Für die Dokumentation:

Operationsverstärker / Induktivitätssimulation / Eigenfrequenz

1. Introduction

There are several realizations available in the literature to simulate a nonideal inductor using active *RC* circuits [1—4].

The utilization of the operational amplifier (OA) roll-off characteristics in the simulation of a nonideal inductor was introduced by Allen and Means [5]. Recently three active *R* resonators based on the OA rolloff characteristics were given [6].

In this paper a novel simple active *R* realization of a nonideal grounded inductor is given. The inductance can be easily controlled by varying a single grounded resistor. A method for converting the circuit to realize a floating inductor is illustrated.

2. The grounded inductor simulation

Fig. 1 a represents the new active R realization of the nonideal grounded inductor.

Taking

$$A = \frac{GB}{s} \tag{1}$$

where GB is the unity gain crossover radian frequency of the OA. By direct analysis the input admittance to the circuit is given by

$$Y_{in} = \frac{1}{R} + \frac{1}{R_1 + R_2} + \frac{K \cdot GB}{s\,R} = \frac{1}{R_{eq}} + \frac{1}{s\,L_{eq}} \tag{2}$$

which is represented by the equivalent circuit shown in Fig. 1 b, where

$$R_{eq} = R//(R_1 + R_2)\,, \tag{3}$$

$$L_{eq} = \frac{R}{K \cdot GB} \tag{4}$$

and

$$K = \frac{R_2}{R_1 + R_2}\,. \tag{5}$$

It is seen that the grounded resistor R_1 controls the magnitude of L_{eq}. Taking $(R_1 + R_2)$ much larger than R, equation (3) reduces to

$$R_{eq} \simeq R\,. \tag{6}$$

In this case the quality factor of the inductor is given by

$$Q \simeq \frac{K \cdot GB}{\omega}\,. \tag{7}$$

It should be noted that for frequencies much less than the unity gain crossover frequency of the OA the inductor realized is very selective.

From equation (4) the sensitivities of L_{eq} to all circuit components are given by

$$\left.\begin{array}{lll} S^{L_{eq}}_{GB} = -1\,, & & S^{L_{eq}}_{R} = 1 \\ S^{L_{eq}}_{R_1} = \dfrac{R_1}{R_1 + R_2} & \text{and} & S^{L_{eq}}_{R_2} = -\dfrac{R_1}{R_1 + R_2} \end{array}\right\} \tag{8}$$

It is clear that $|S^{L_{eq}}_{x}| \leq 1$where x stands for any active or passive circuit component, which means very small sensitivities.

3. The floating inductor simulation

It is well known that the realization of a floating inductor is a much more difficult problem than that of realizing a grounded version. Here a novel active R realization of a lossy floating inductor is introduced. Fig. 2 a represents the new active R circuit realization. Taking $A = \frac{GB}{s}$ and $A' = \frac{GB'}{s}$ and by direct analysis, the short circuit admittance matrix of the two port network is given by

$$[Y] = \begin{bmatrix} \dfrac{GB}{s\,R} + \dfrac{1}{R} & -\dfrac{GB}{s\,R} \\ -\dfrac{GB'}{s\,R'} & \dfrac{GB'}{s\,R'} + \dfrac{1}{R'} \end{bmatrix}. \tag{9}$$

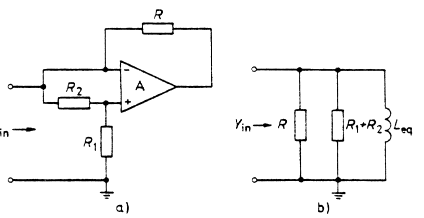

Fig. 1: The new active R realization of a nonideal grounded L (a) and the input admittance equivalent circuit (b)

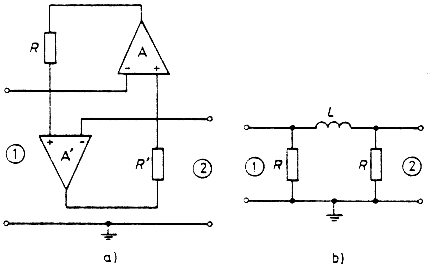

Fig. 2: The new active R realization of a nonideal floating L (a) and the equivalent circuit (b)

Assuming identical OAs and taking $R = R'$, the admittance matrix of the network becomes

$$[Y] = \begin{bmatrix} \dfrac{GB}{s\,R} + \dfrac{1}{R} & -\dfrac{GB}{s\,R} \\ -\dfrac{GB}{s\,R} & \dfrac{GB}{s\,R} + \dfrac{1}{R} \end{bmatrix} \tag{10}$$

which is represented by the equivalent circuit of Fig. 2 b where $L = R/GB$.

The practicality of the proposed network of Fig. 2 a is restricted to the use of dual OAs having closely matched characteristics which track with changes in voltage and temperature. These dual OAs are now available at low cost. It is noted that the circuit simulates almost an ideal floating inductor for frequencies much less than the unity gain crossover frequency of the OA.

The π equivalent circuit shown in Fig. 2 b should be compared with the simplified circuit model in the form of a π of inductors obtained by using two gyrators and a grounded capacitor in between to simulate a floating inductor [7].

References:

[1] Ford, R. L.; Girling, F. E. J.: Active filters and oscillators using simulated inductance. Electron Letters (1966) 2, p. 52.
[2] Dutta Roy, S. C.: On operational amplifier simulation of grounded inductance. Arch. elektr. Übertrag. 29 (1975) pp. 107–115.
[3] Newcomb, R. W.: Active integrated circuit synthesis. Prentice Hall, New Jersey, 1968.
[4] Soliman, A. M.; Awad, S. S.: A Tunable Active Inductance Using a Single Operational Amplifier and its Applications in Filters. Arch. elektr. Übertrag. 32 (1978) 1, pp. 44–48.
[5] Allen, P. E.; Means, J. A.: Inductor simulation derived from an amplifier rolloff characteristics. Transact. Inst. Electron. Engrs. CT–19 (1972) pp. 395–396.
[6] Soliman, A. M.; Fawzy, M.: Active R resonator realization. Proceedings of the Inst. of Electr. and Electronc. Eng. 66 (1978), (accepted for publication).
[7] Moschytz, G. S.: Linear integrated networks fundamentals. Van Nostrand Reinhold Company, New York, 1974, p. 301.

Dr. Ahmed M. Soliman, 20 A El-Mansour Mohamed Str., Apt. 51, Zamalek, Cairo, Egypt.

(Received on January 24th, 1978)