This paper describes the transaction to generate and measure negative valued resistors, capacitors and inductors in Pspice simulation medium for an educational purpose. Negative circuit components are designed and their defining characteristics are produced. An op-amp based generic circuit is used for obtaining negative components. To extract characteristics, a charge-meter and a flux-meter are designed and utilized, in addition to the conventional meters (markers) in the Pspice environment. The study of the paper have educational value in making clear the meaning of negative impedance by experimentation in a simulation medium, thus relating theory to practice and also exhibit that ORCAD Pspice is highly visual and effective for both understanding the mathematical theory underlying the circuits and performing measurements of flux and charge which are needed to obtain the characteristics of negative inductors and negative capacitors.

Keywords: Simulation, OrCAD PSpice, negative resistor, negative capacitor, negative inductor, flux-meter, charge-meter

1. Introduction

The development of computer technology has opened new perspectives in engineering education to prepare students for their needs. In this context computer simulation has been a commonly adopted technique for predicting the real world behaviour of a component, circuit or system. PSpice has existed for some time and is a much popular circuit analysis program used by many electrical engineers and by Universities in their engineering courses as a CAD tool to analyse and test circuitry, because of its simplicity and effectiveness [1–5]. Pspice Simulator also provides the advantage of using hierarchical structures, thus simplifying the design and rendering the drawings more manageable.

This paper presents a design and simulation study for negative impedance emulation in Pspice simulation medium. Generally, negative impedances (admittances) can be used in generation of transfer functions or impedance functions, which are not physically realizable without active circuits. Specifically, negative impedance emulators play an important role in cancellation/compensation of parasitic impedances [6]. They also have applications in microwave circuits for impedance matching [6,7,8,9] and realization of chaotic oscillations [10,11,12]. The study presented is of educational value and has two facets: obtaining systematically all kind of negative valued circuit components, namely, resistors, capacitors and inductors, which are presented in Section 2; generating their characteristics using flux – meters and charge meters, additional to already existing voltage and current meters, designed in the same environment, which is provided in Section 3 together with simulation results. Finally, Section 4 covers the discussion.

2. Generation of Negative Components

The generic circuit used for obtaining negative components systematically is shown on Figure 1. The two-port active device is a universal operational device, such as an opamp or current conveyor and it does not draw any current at the input.
From the straightforward analysis of the circuit,

\[ Z_i = \frac{V_i}{I_i} \quad (1) \]

and remembering the current input to the active element is zero,

\[ I_i = \frac{V_i(1 - K)}{Z} \quad (2) \]

and finally substituting (2) in (1) yields,

\[ Z_i = \frac{Z}{1 - K} \quad (3) \]

If K is chosen specifically as 2 then the input impedance of the overall becomes,

\[ Z_i = -Z \quad (4) \]

from which negative value resistors, capacitors and inductors are derived.

3. Expression of Characteristics in Pspice Environment

In this Section negative components are obtained moving from the Figure 1 and numerical simulations are performed with an aim of extracting their defining characteristics. From the basic theory, the defining equations for the resistor, capacitor and inductor, respectively, are as follows

\[ V = R I \quad (5) \]

\[ Q = C V \quad (6) \]

\[ \Psi = L I \quad (7) \]

In the measurement procedure for (5), the voltage and current markers, already existing within the structure of Pspice, are used. Whereas a charge-meter and flux-meter needed for (6) and (7), respectively, are constructed using sensing elements and integrators, whose details are illustrated on the relevant figures.
3.1. Negative resistor

The generative circuit and related measurement arrangement for producing the characteristic of the negative resistor is illustrated below on Figure 2. In Pspice dc analysis was performed changing \( V_{\text{test}} \) between -5V and 5V, thus obtaining the V-I characteristic as given on Figure 3.

![Figure 2. Negative resistor generation and measurement circuit](image)

![Figure 3. The defining characteristic for the negative resistor of Figure 2](image)

The vertical and horizontal axis represents the voltage across and current through the component, respectively. The measurement was performed as required by (5) using a voltmeter and an ammeter.
3.2. Negative capacitor

The generative circuit and related measurement arrangement for producing the characteristic of the negative capacitor is illustrated below on Figure 4. In Pspice time analysis was performed for one period, thus obtaining the Q-V characteristic as given on Figure 6. The charge-meter designed for this aim is provided on Figure 4 both as a block and inside look.

Figure 4. Negative capacitor generation and measurement circuit

Figure 5. The voltage across and charge through the negative capacitor for one period of the alternating input voltage
Figure 6. The defining characteristic for the negative capacitor of Figure 4. The vertical and horizontal axis represents the charge through and voltage across the component, respectively. The measurement was performed as required by (6) using a charge-meter and a voltmeter.

3.3 Negative Inductor

The generative circuit and related measurement arrangement for producing the characteristic of the negative inductor is illustrated below on Figure 7. In Pspice time analysis was performed for one period, thus obtaining the Ψ-I characteristic as given on Figure 9. The flux-meter designed for this aim is provided on Figure 7 both as a block and inside look.

Figure 7. Negative inductor generation and measurement circuit
Figure 8. The flux across and current through the negative inductor for one period of alternating input voltage

Figure 9. The defining characteristic for the negative inductor of Figure 7. The vertical and horizontal axis represents the flux across and current through the component, respectively. The measurement was performed as required by (7) using a flux-meter and an ammeter

4. Conclusions

In this study all types of two-terminal negative circuit components are generated from a single opamp circuit, complete with a simulation work in Pspice environment for obtaining their defining characteristics, which required the construction of a charge-meter (Fig. 4) and a flux-meter (Fig. 7) for educational purpose. The results are proved quite well in verifying and illustrating the underlined circuit theory, and as such have an educational value. It is apparent (Fig. 1) that the components obtained are all grounded. Besides, the voltage and current range of them are determined by the supply voltage and output current, respectively.

References

1. PSpice User’s manual. OrCAD Corp. (Cadence Design Systems, Inc.)
2. OrCAD Capture User’s Guide. OrCAD Corp. (Cadence Design Systems, Inc.)


