

Design of Operational Amplifier Simulator

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Abstract

Operational amplifier (op-amp) is widely used in electronic engineering. Therefore their analysis and synthesis must be thoroughly comprehended. The study, which was carried out .NET and MATLAB based simulator, is designed for operational amplifier application circuit. Besides basic amplification operations (phase inverting, phase non-inverting, buffer), the simulator can perform mathematical operations (summing, subtraction, multiplication, division, differentiation, integration, exponentiation, logarithm etc) and filtering operation. Due to the interactive interface of modules, simulator can also be used for educational purposes, analysis and synthesis of op-amp circuits can be realized easily and greater accuracy.

Key words: Operational amplifier, simulator, .NET, MATLAB

1. Introduction

Operational amplifiers (op-amps) have a very wide range of use which consists of the most simple amplification operations, mathematical operations, filtering operations, analog-to-digital, digital-to-analog conversion operations, and signal generators in industrial and scientific fields. Therefore, main principles of such structures must be completely comprehended.

In the technical field, theoretical information must be used in practical applications for reinforcing knowledge. But insufficient opportunities for laboratory experiments, absence of application fields and complexity of the circuits make it difficult. For this reason, instead of practical implementation, simulations on computers are preferred. In the literature many simulator studies were performed on different topics in the field of electrical and electronics[1-3].

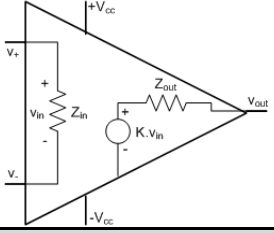
In this study, a simulator is designed for operational amplifiers. While interface of the simulator is created using Visual Studio based on .NET [4], analysis are generated using MATLAB [5]. Basic applications of operational amplifiers (amplification, mathematical operations, filtering) can be interactively performed with the simulator. So the effects of circuit parameters can be simultaneously observed.

2. Materials and Method

2.1. Operational amplifier

Operational amplifiers are differential amplifiers which have very high input and very low output impedance (Table 1). They have also very high open loop gain. Operational amplifiers can be used for different purposes with connecting appropriate components their terminals [6-8].

Table 1. Ideal and Non-ideal Op-amp and Some Parameters

		
<i>Some parameters</i>	<i>Ideal op-amp</i>	<i>Non-ideal (real) op-amp</i>
<i>Input impedance</i>	Infinite	Finite
<i>Output impedance</i>	Zero	Non-zero
<i>Open-loop gain</i>	Infinite	Finite
<i>Input current</i>	Zero	Non-zero
<i>Input offset voltage</i>	Zero	Non-zero
<i>Bandwidth</i>	Infinite	Finite
<i>Noise</i>	Zero	Non-zero
<i>CMRR</i>	Infinite	Finite
<i>Slew rate</i>	Infinite	Finite

2.2. The designed simulator

In design stage of this simulator, two programming language was used. Main attributes of operational amplifiers were established in MATLAB. After operational amplifiers basic methods were written in MATLAB, due to creating interactive interface, the methods were placed in a class named as “OpampClass” and using deploytool command, the class passed .dll file named as opamp_lib.dll This file was attend references in the WPF project which was supplied by .NET. The other .dll file named as MWArray.dll which has directory MATLAB was also joined WPF project’s reference. In order to disposing “OpampClass” and Matlab data types, required statements attend to the .NET project’s code. We used two data types in C# for invoking Matlab. The first and widely used is MWNumericArray which holds matrix information and the second is MWCharArray which holds string array used for selecting wave shape. The interactive part of program was designed in .NET using events. For developing interactive interface, necessary events were declared such as ValueChanged belongs to scrollbar’s event. Whole program was built with following this programming technique.

Main window of designed simulator is shown in Fig. 1. The following operations can be performed using these screen menus,

- File: Creating new simulation, Opening a previously saved simulation, saving simulation which was performed and printing operations.
- Basic Circuits: Phase inverting, phase non-inverting, buffer, current to voltage – voltage to current conversion operational amplifier applications.
- Mathematical Circuits: Summing, subtraction, multiplication, division, multiplication by a constant, differentiation, integration, logarithm, antilogarithm (exponentiation) operational amplifier applications.
- Filter Circuits: Low pass, high pass, band pass and band stop operational amplifier applications.
- Help: Information about program and operational amplifiers.

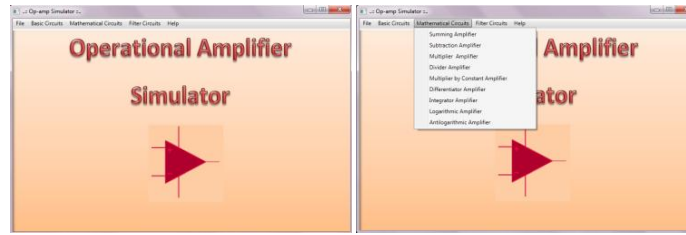
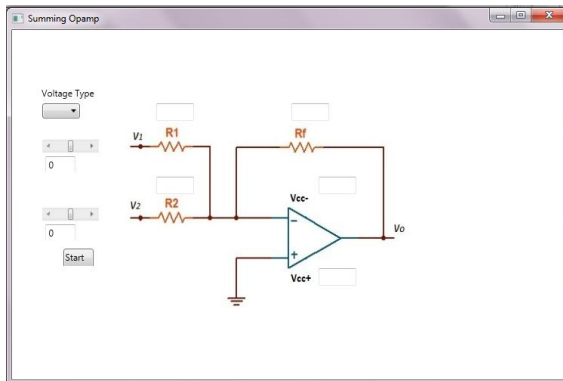


Figure 1. Main screen of designed simulator

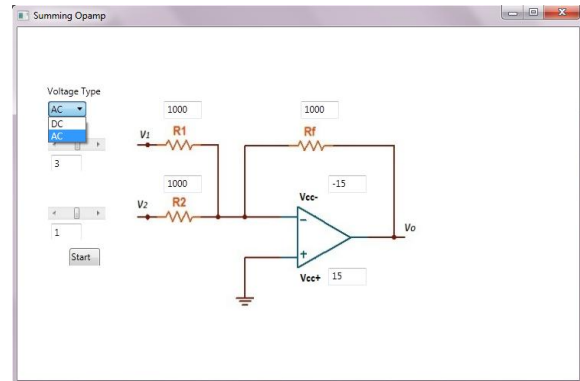
3. Simulations

As first simulation, the steps of summing two AC signals $+1.\sin(2\pi t)$ and $+3.\sin(2\pi t)$ are shown in Fig. 2. In program screen, resistors and supply voltages parameters of summing operational amplifier circuit are entered, the voltage types which will be summed is selected and the input voltage values are arranged or typed with scroll bar. The simulation is initialized with clicking start button and input - output voltages can be seen on same screen.

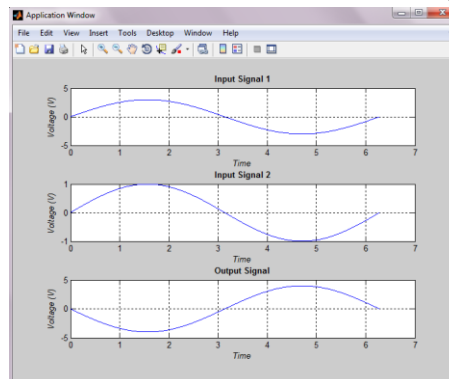
$$v_0 = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2\right) = -\left(\frac{1.10^3}{1.10^3} \cdot 1.\sin(2\pi t) + \frac{1.10^3}{1.10^3} \cdot 3.\sin(2\pi t)\right) = -4.\sin(2\pi t) \quad (1)$$



(a) Main screen of summing amplifier



(b) Select voltage type, input amplitudes of voltages and circuit's parameters

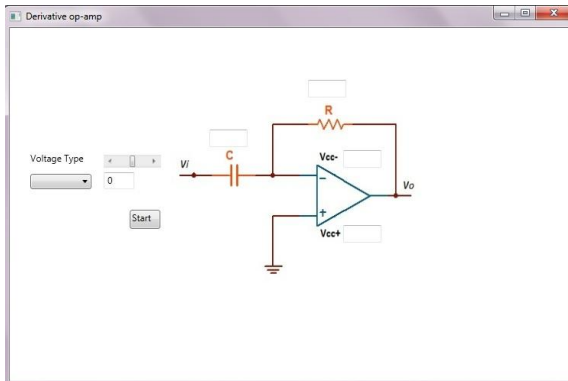


(c) Result (output) screen of the first simulation

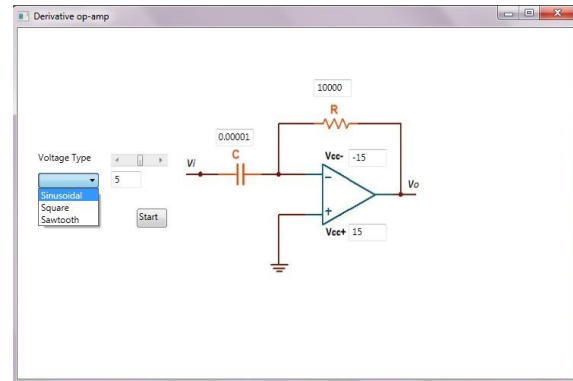
Figure 2. Steps for summing amplifier simulation

As second simulation, derivation of AC signal $+5.\sin(2\pi t)$ is shown in Fig. 3.

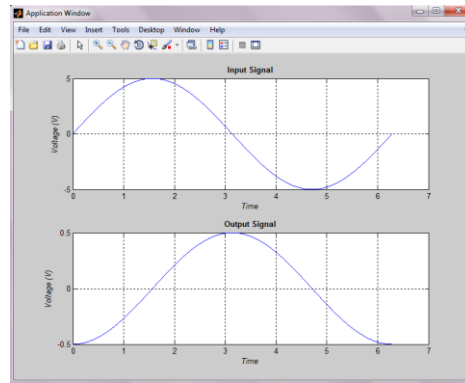
$$v_0 = -R.C \frac{dv_i}{dt} = -10^4 \cdot 10^{-5} \frac{5 \cdot \sin(2\pi t)}{dt} = -0.5 \cos(2\pi t) \quad (2)$$



(a) Main screen of derivative amplifier

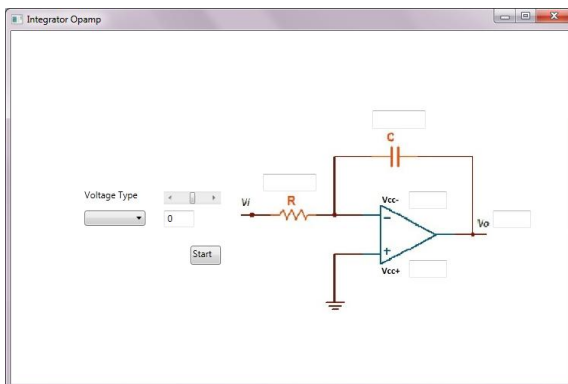


(b) Select voltage type, input amplitude of voltage and circuit's parameters

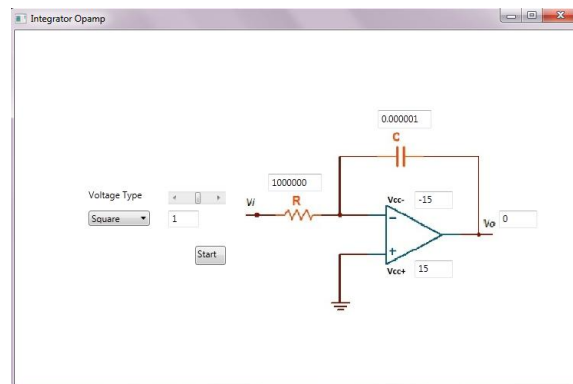
(c) Result (output) screen of the second simulation
Figure 3. Steps for derivative amplifier simulation

As third simulation, the integration of unit step which has +1V amplitude is shown in Fig. 4.

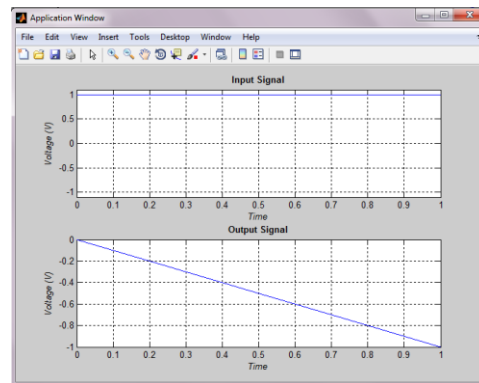
$$v_0 = -\frac{1}{R.C} \int v_i dt + v_0(0) = -\frac{1}{1.10^6 \cdot 1.10^{-6}} \int 1. dt = -t \quad (3)$$



(a) Main screen of integrator amplifier

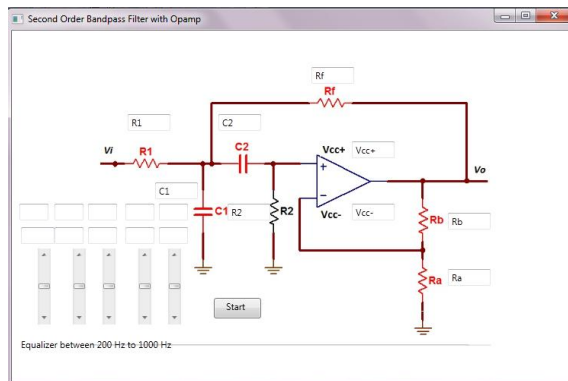


(b) Select voltage type, input amplitude of voltage and circuit's parameters

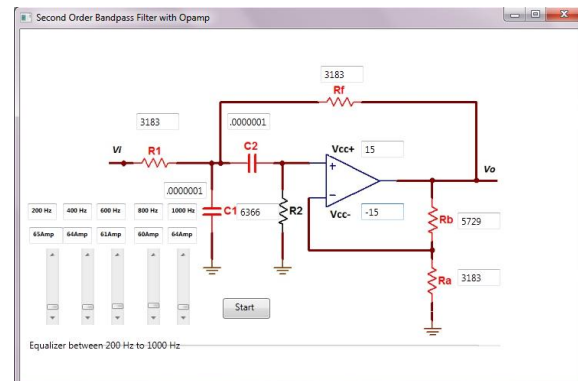


(c) Result (output) screen of the third simulation
Figure 4. Steps for integrator amplifier simulation

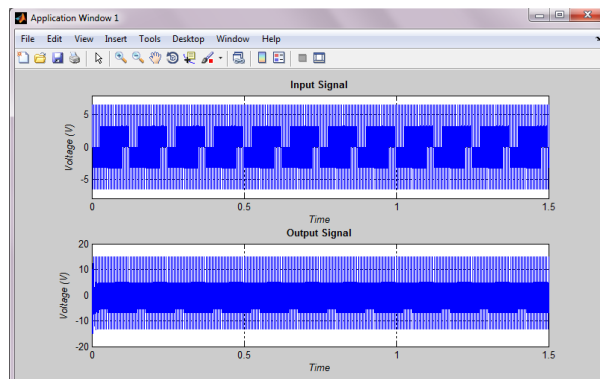
As the last simulation, band pass filter application is given. Signal which comprises 200, 400, 600, 800 and 1000 Hz frequencies and conveys above 60 V amplitude for per frequency component is supplied to input. According to input the 400 Hz signal component was passed the filter effectively, the 200 Hz was passed partially and the other components were suppressed efficiently [9]. The simulator results can be plotted both time domain and frequency domain.



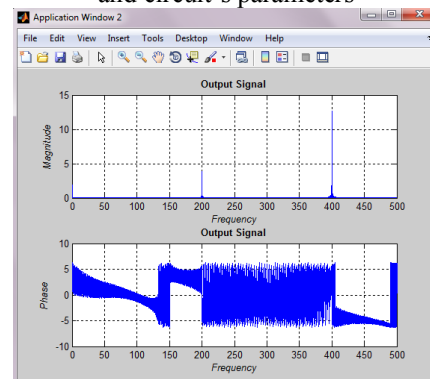
(a) Main screen of band-pass filter simulation



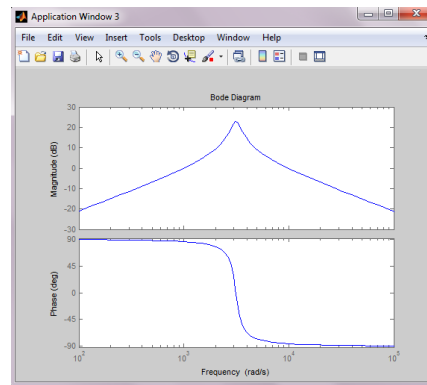
(b) Select frequencies and amplitudes of input voltage and circuit's parameters



(c) Time domain



(d) Frequency domain



(e) Bode diagram

Figure 5. Steps for band-pass filter simulation

4. Conclusions

In the study which was carried out, a simulator for basic applications of operational amplifiers was designed. The analysis and synthesis of operational amplifier circuits can be performed effectively, efficiently and quickly with this program which can be easily used by people who study or realizing projects in electric – electronic field. In future work, extending content of the simulator and making the simulator accessible through network is aimed.

References

- [1] Feisel L.D. and Rosa A.J. The role of laboratory in undergraduate engineering education. *Journal of Engineering Education* 2005; 121-130.
- [2] Balamuralithara B. and Woods P. C. Virtual laboratories in engineering education: The simulation lab and remote lab. *Computer Applications in Engineering Education* 2009; 17:108-118.
- [3] Sevgi L. Electrical and Computer Engineering Education in the 21st Century: Issues, Perspectives and Challenges. *Turk. J. Elec. Engin.* 2006; 14 (1): 1-5.
- [4] Microsoft Corporation (<http://www.microsoft.com/visualstudio>)
- [5] MATLAB, The MathWorks, Inc.
- [6] http://en.wikipedia.org/wiki/Operational_amplifier
- [7] Nilsson J.W. *Electric Circuits*. Fourth ed. Addison-Wesley Publishing Company; 1993.
- [8] Boylestad R. and Nashelsky L. *Electronic Devices and Circuit Theory*. 5th ed. Prentice Hall; 1992.
- [9] Dorf R.C. and Svoboda J.A. *Introduction to Electric Circuits*. John Wiley & Sons; 2004.