Teaching Some Applications of Operational Amplifiers by Aid Using Simulink

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Abstract—Electronics technology is an important field in many scientific and practical applications , and it has been found that most modern electronic devices needs an operational amplifiers to increase the level of voltage or current signals or amplification of the signals .

This paper presents some examples of simulated experiments using Simulink as demonstration to students to make them understanding the fundamentals of operational amplifier (Op-Amp) applications . The simulated experiments deal with using an OP –Amp as a inverting , non inverting, summer, subtractor, integrator and differenator , …etc Also an operational amplifiers in an important element in the design of an active filters. .Students can easily learn how to experiment with these softwares in order to learn at their own time and pace. This helps visualize the fundaments of Op-Amp as well as any other physical system

Keywords—Operational Amplifier, OP- Amp, Simulink, LPF, HPF and BPF.

I. INTRODUCTION

An Op-Amp is an integrated circuit that uses external voltage to amplify the input through a very high gain ,The process amplifier consists of a direct-gain amplifier with a large gain. Additive feeder to control its properties is used to accomplish different linear functions and some nonlinear functions. The operational amplifier is small, reliable and low cost, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals. Operational amplifiers had their origins in analog computers, where they were used to perform mathematical operations in many linear, non-linear, and frequency-dependent circuits. [1]

The popularity of the op-amp as a building block in analog circuits is due to its versatility. By using negative feedback, the characteristics of an Operational Amplifier circuit, its gain, input and output impedance, bandwidth etc. are determined by external components and have little dependence on temperature coefficients or manufacturing variations in the Operational Amplifier itself. [2, 3[.

Operational Amplifier are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices. Many standard IC Operational Amplifier cost only a few cents in moderate production volume; however, some integrated or hybrid operational amplifiers with special performance specifications may cost over US$100 in small quantities. Operational Amplifier may be packaged as components or used as elements of more complex integrated circuits.[1]

II. OPERATIONAL AMPLIFIERS BASIC OPERATION

Operational amplifiers are nonlinear devices that have all the properties required for nearly ideal DC amplification and are used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.

An Operational Amplifier, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier". [4, 5].

An Operational Amplifier is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the Inverting Input, marked with a negative or "minus" sign, (–). The other input is called the Non-inverting Input, marked with a positive or "plus" sign (+).

A third terminal represents the operational amplifiers output port which can both sink and source either a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.[3, 6]

- Voltage – Voltage "in" and Voltage "out"

- Current – Current "in" and Current "out"

- Transconductance – Voltage "in" and Current "out"

- Transresistance – Current "in" and Voltage "out"

III MODELING AND SIMULATION OF AN OP-AMP CICUITS APPLICATIONS

In this work it implement and simulate operational amplifier circuits using Simulink . These circuits are working as inverter , non-inverter, summer, subtractor , integrator, differentiator, low pass filter, high filter and band pass filter circuits. These implement and simulate circuits are as clarified in the following points:

A. INVERTING OP-AMP CICUIT

The inverting op-amp circuit model is implemented using Simulink as shown in figure 1. The gain is given by $-R2/R1$, and with the chosen values of R_1=1K Ohm and R_2=1K Ohm. Then applied at the input of the simulation circuit input voltage 2V peak-to-peak and with frequency of 1KHz. After implementing the inverting circuit and setting all the simulation and equipment parameters . The displayed achieved simulation result are represented on scope as shown in Fig.1
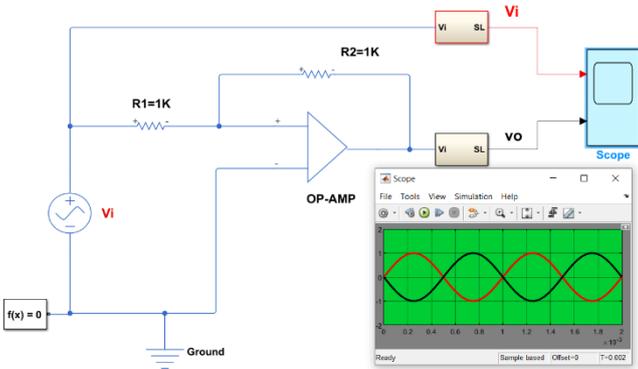

Fig.1. Simulation Inverting Circuit diagram of an Op-Amp and Simulation Results

B. NON INVERTING OP-AMP CIRCUIT

contracted using Simulink as illustrated figure 2 . The gain is given by 1+R2/R1, and with chosen t values of R_1=1K Ohm and R_2=1K Ohm. Then applied at the input of the circuit input voltage 2V peak-to-peak and with frequency of 1KHz. After that set the simulation and equipment parameters of an non inverter circuit and then the realized simulation result are displayed on scope as shown in Fig.2.
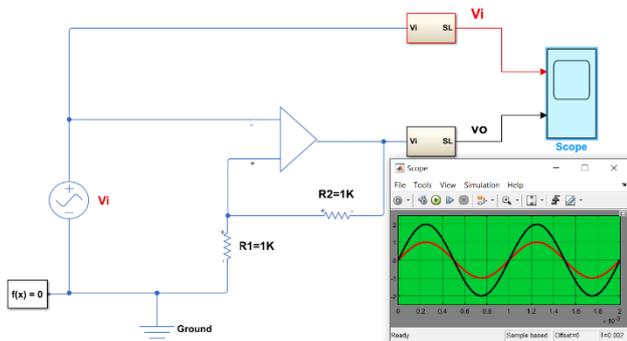

Fig. 2. Simulation Non Inverting Circuit diagram of an Op-Amp Simulation Results

C. SUMMING OP-AMP CIRCUIY

An op-amp circuit model working as a summer is implemented using Simulink as illustrated in figure 3 Assuming that the resistances values of the summer circuit are R1=R2= Rf=1K Ohm. Then applied at the input of the summer circuit two input voltages with 2V peak-to-peak values each and their frequencies are 1KHz After that set the simulation equipment parameters of the simulation circuit. After that the apprehend simulation result are displayed on scope as shown in Fig. 3.
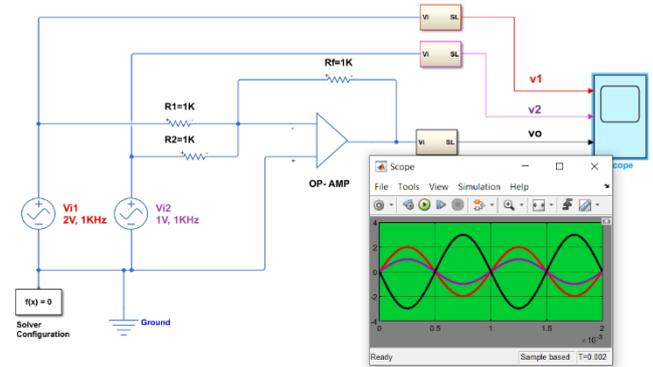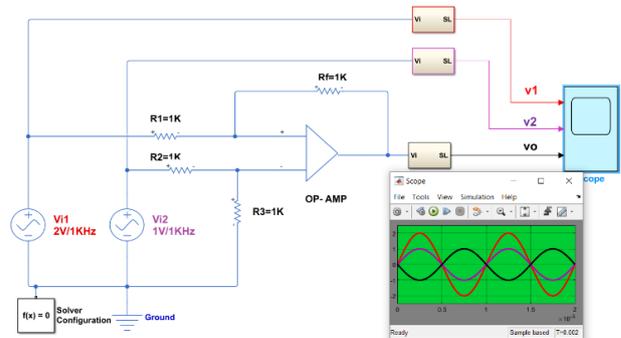

Fig.3. Simulation Summer Circuit diagram of an Op-Amp and Simulation Results

D. SUBRACTOR OP-AMP CIRCUIT

The circuit model of an op-amp working as a subtractor is implemented using Simulink as illustrated figure4. Assuming that the resistances values of the circuit are R1=R2= Rf=1K Ohm. Then applied at the input of the summer circuit two input voltages with 2V peak-to-peak values each and their frequencies are 1KHz each . After implementation of the simulation circuit setting all the simulation and equipment parameters of the simulation circuit and then the apprehend simulation result are displayed as shown in Fig. 4.

Fig. 4. Simulation Subtractor Circuit diagram of an Op-Amp and Simulation Results

E. INTEGRATOR OP-AMP CIRCUIY

The integrator op-amp circuit model is constructed using Mat Simulink as shown in figure 5. The values of circuit are are chosen to be R=1K Ohm and C=0.2uf. Then applied at the input of the circuit input voltage 2V peak-to-peak and with frequency of 1KHz. After that setting all the simulation and equipment parameters of the simulation circuit and then the achieved simulation result are displayed on scope as represented in Fig.5.
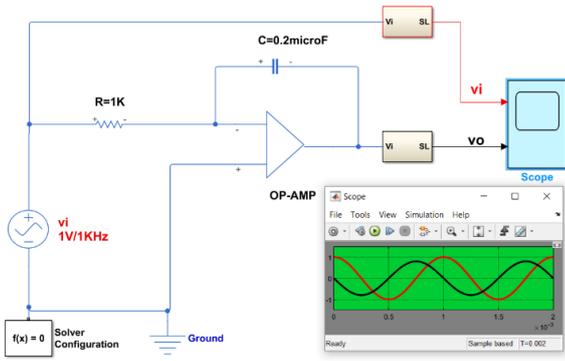
Fig. 5. Simulation Integrator Circuit diagram of an Op-Amp and Displayed Simulation Results
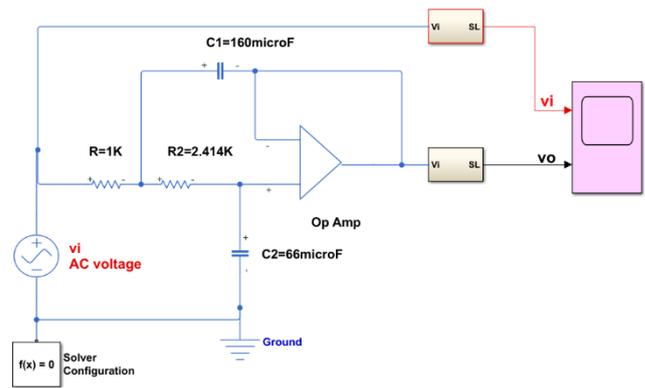
F. DIFFERNATIONAL OP-AMP CIRCUIY

The differenational op-amp circuit model is implemented using Simulink as shown in figure 6. The values of circuit are assumed to be R=1K Ohm and C=0.2uf. Then applied at the input of the circuit input voltage 2V peak-to-peak and with frequency of 1KHz. After that setting all the simulation and equipment parameters of the simulation circuit . Then the obtained simulation result are displayed on scope as represented in Fig.6.
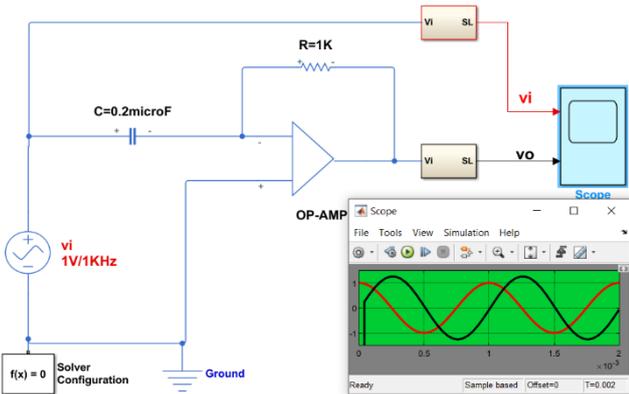

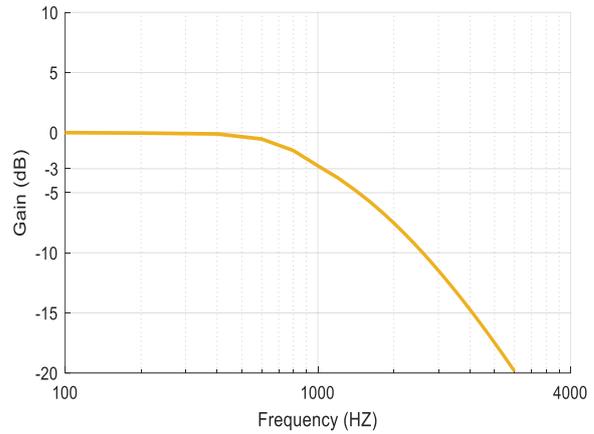Fig. 6. Simulation differnator Circuit diagram of an Op-Amp and Displayed Simulation Results

G. SIMULATION OF AN ACTIVE 2nd ORDER FILTERS

The active 2nd order low pass, high pass and band pass filters are implemented using Simulink tool will be demonstrated in the following points.

- Second Order Low Pass Filter

The 2nd order low pass filter (LPF) circuit model is implemented using Simulink as shown in Fig.7. With the cut-off frequency 1KHz and values of the filter elements are R_1=1KΩ, R_2=2.414KΩ, C_1=160nF and C_2=66nF. Then applied at the input of the circuit 2V peak-to-peak sinusoidal signal and with frequency range from 100Hz to 4000HKz . After that setting all the simulation parameters of the simulation circuit. Then the obtained simulation result is clarified the frequency response of the 2nd order LPF as represented in Fig. 8.

Fig. 7. Simulation Circuit Model of 2nd Order Low Pass Filter

Fig. 8. Frequency Response of 2nd Order Low Pass Filter

- Second Order High Pass Filter

The 2nd order high pass filter (HPF) circuit model is implemented as shown in Fig. 9. using Simulink by replacing the resistances (R_1 and R_2) by capacitors (C_1 and C_2) and capacitors (C_1 and C_2) by resistances (R_1 and R_2) in the LPF circuit shown in Fig.7. After that applied at the input of the circuit 2V peak-to-peak sinusoidal signal and with frequency range from 100Hz to 4000KHz. After setting all the simulation parameters of the simulation circuit and running the cicuit . Then the obtained simulation result is clarified the frequency response of the 2nd order LPF as represented in Fig. 10.
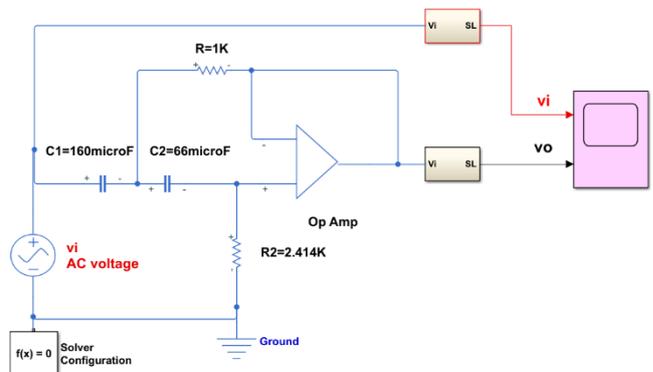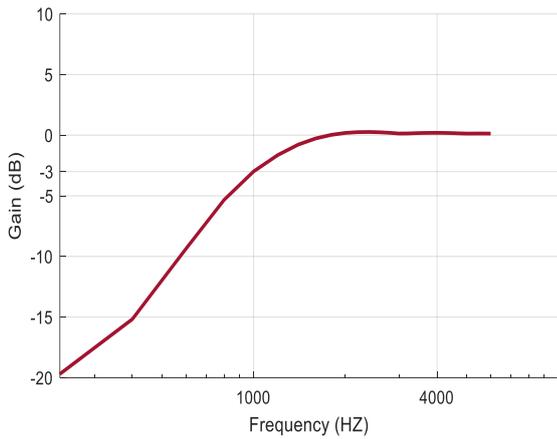

Fig. 9. Simulation Circuit Model of 2nd High Filter

Fig. 11. Simulation Circuit Model of Band Pass Filter

Fig. 10. Frequency Response of Band Pass Filter

Fig. 10. Frequency Response of 2nd Order High Pass Filter

- Band Pass Filter

Band bass filter can be implemented by connect low pass filter circuit with high pass filter circuit series using Simulink tool as shown in Fig.11. While the cut-off frequency of the LPF is the 3KHz and the cut-off frequency of HPF is 1kHz.. The values of the filter elements are R_1= R_3=1KΩ, R_2=R_4=2.414KΩ, C_1=53.3nF, C_2=22nF, C_3=160nF and C_4=66nF. Then applied at the input of the filter   2V peak-to-peak sinusoidal signal and with frequency range from 100Hz to 4000HKz   . After   setting all the simulation parameters of the simulation BPF while the obtained simulation result is illustrated   the frequency response of the BPF as represented in Fig. 12.
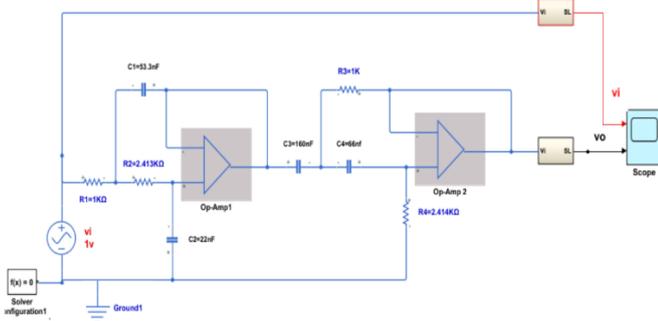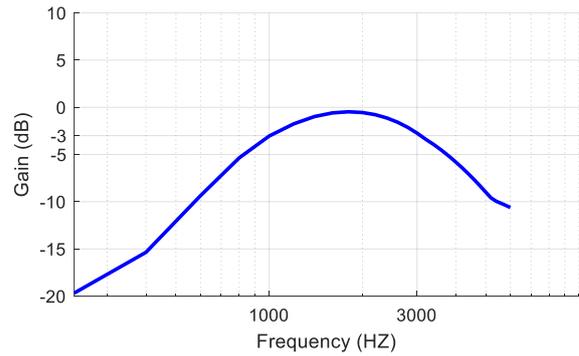

IV CONCLUSION

The Main fundamental operational amplifier   applications such as buffer, inverter, non-inverter, summer, subtract, differentiator and integrator   as well as an active low pass, high pass and band pass 2nd order filters were Implemented using Simulink carried out.

It is shown that simulation of the applications of an operational amplifiers are not too difficult and that simulation provides a good approach for learning. The modern software can be used to simulate almost any physical system and to experiment it without having to build it as well as save time and cost.

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