



Simulation Software as a Teaching Aid for Some Electronic Circuits Applications

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OP-Amp.

ABSTRACT

Electronic circuit technology is an important field with several scientific and practical applications. and that technology has been found that most modern electronic devices required nonlinear elements such as diodes, Transistors and operational amplifiers. Diodes have a variety of applications in electronics, including rectification, voltage demodulators, voltage regulation, logic gates and so on. In addition, transistors have many applications, which are widely used in electronics for amplification, switching, digital logic circuits, Power regulation, and oscillators. However, op-amps are electronic devices that can be used in a wide range of applications including Amplification, inverting, noninverting, summers, integrators, filtering, and comparators.

This paper presents some examples of experimental simulation using Simulink software as a demonstration to students to make them understand the fundamentals of these nonlinear elements. Some experimental simulations were dealt with using diodes as a half-wave rectification, full-wave rectifier voltage regulator, and voltage limiter. However, the other experimental simulations dealt with OP-amp as an inverting, non-inverting, summer, subtractor, integrator and differentiator. Additionally, an operational amplifier is an important element in the design of active filters. Students can easily learn how to make experiment with this software in order to learn at their own time and pace. This helps visualize the fundamentals of Op-Amp as well as any other physical system.

برامج المحاكاة كأداة تعليمية لبعض تطبيقات الدوائر الإلكترونية

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الكلمات المفتاحية:

الديود
نصف الموجة
الموجة الكاملة
منظم الجهد
محدد الجهد
المضخمات

المخلص

أجريت تعد تقنية الدوائر الإلكترونية مجالاً مهماً له العديد من التطبيقات العلمية والعملية. قد تبين أن معظم الأجهزة الإلكترونية الحديثة تتطلب عناصر غير خطية مثل الثنائيات والترانزستورات ومضخمات التشغيل. للثنائيات مجموعة متنوعة من التطبيقات في مجال الإلكترونيات، بما في ذلك التصحيح، ازالة تشكيل الجهد، تنظيم الجهد، البوابات المنطقية وما إلى ذلك. بالإضافة إلى ذلك، فإن للترانزستورات العديد من التطبيقات، حيث يتم استخدامها على نطاق واسع في مجال الإلكترونيات للتضخيم والتبديل والدوائر المنطقية الرقمية وتنظيم الطاقة والمذبذبات. ومع ذلك، فإن أجهزة المضخمات هي أجهزة إلكترونية يمكن استخدامها في مجموعة واسعة من التطبيقات بما في ذلك التضخيم، والانعكاس، ولا انعكاس، والمكامل، المرشحات، المقارنات وغيرها. تقدم هذه الورقة بعض الأمثلة على المحاكاة التجريبية باستخدام برنامج Simulink كإيضاح للطلاب من اجل جعلهم يفهمون أساسيات هذه العناصر غير الخطية. تم التعامل مع تجارب المحاكاة باستخدام الثنائيات مثل تقويم نصف الموجة، منظم جهد الموجة الكاملة، محدد الجهد. بالإضافة الى ذلك، تم التعامل مع عمليات المحاكاة التجريبية الأخرى مع المضخمات على أنه كعكس وغير عاكس وجامع ومكامل. إضافة إلى ذلك، تعد للمضخمات التشغيلية عنصرًا مهمًا في تصميم المرشحات النشطة. يمكن للطلاب بسهولة تعلم كيفية اجراء التجارب باستخدام هذا البرنامج مما يساعد على فهم وتصور أساسيات المضخمات او أي نظام فيزيائي.

1.Introduction

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In order to study more in-depth professional knowledge, students need to establish a solid foundation by mastering the fundamental theory, fundamental knowledge, and fundamental abilities of electrical circuits. By simulating the circuit with virtual simulation software, which is free from the impacts of the experimental environment and instrument as well as the risk of component damage and physical injury, safety can be increased. Additionally, by allowing students to view the signal waveforms of various electronic circuits in real-time through virtual simulation tools, the effectiveness of classroom instruction is considerably enhanced. [1]

A diode is a two-terminal electronic component that allows current to flow in only one direction. It is typically made of a semiconductor material such as silicon or germanium and has a p-n junction, which is a boundary between two different types of semiconductor material. When a voltage is applied across the diode, current can flow in one direction, but not in the opposite direction. This property makes diodes useful in a variety of electronic applications, such as rectification, voltage regulation, and signal detection. Diodes come in many different forms, including the popular rectifier diode and light-emitting diode (LED) [2]. They are an essential component in many electronic circuits and have played a key role in the development of modern electronics.

Diodes are widely used in due to their capacity to regulate the flow of electrical current in electronic circuits. They can be used to change AC (alternating current) into DC (direct current), which is required for the proper operation of many electronic devices. Rectifier diodes are commonly used for this purpose, and they are often found in power supplies for electronic devices such as televisions, computers, and smartphones.

Another important use of diodes is in voltage regulation. Zener diodes, for example, are designed to maintain a constant voltage across a circuit, even when the current changes. This property makes them useful in voltage regulator circuits, where a stable voltage is required for electronic devices to operate correctly.

An op-amp is an integrated circuit that amplifies the input using external voltage at a very high gain., the processing amplifier consists of a direct-gain amplifier with a large gain. An 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, The output is single-ended. An op-amp generates an output potential in this configuration that is generally hundreds of thousands of times greater than the potential difference between its input terminals (relative to circuit ground). Operational amplifiers originated in analog computers, where they were employed in numerous linear, non-linear, and frequency-dependent circuits to carry out mathematical calculations. [3]

Because of their adaptability, op-amps are a common component analog electronics uses. External components are used to control the operational amplifier circuit's properties, such as its gain, input and output impedance, bandwidth, etc negative feedback, therefore manufacturing variations or temperature factors have little impact on the operating amplifier itself. [4, 5].

With their widespread application in a wide range of consumer, commercial, and scientific products, operational amplifiers are among the most popular electronic devices available today. Some integrated or hybrid operational amplifiers with unique performance parameters may cost over US\$100 in small numbers, although many typical IC operational amplifiers only cost a few cents in moderate production volumes. Operational amplifiers can be employed as standalone components or as parts of more intricate integrated circuits. [3]

2. Electronic Circuits

2.1. Diode and their application

2.1.1. Half-wave rectification

One of the uses of diodes is half-wave rectification, where the positive part of the input signal can be passed while the negative part of it is blocked. The circuit that performs this function is known as a half-wave rectifier circuit, which is built using Simulink as shown in Figure (1a). The circuit includes a diode and a load resistor with a value of 1 kilo-ohm, as well as a signal generator. A test signal with an amplitude of 5 volts and a frequency of 1 kilohertz was applied to the input of the circuit shown in Figure (1a) After simulating the circuit, the

simulation results were obtained, which include the input voltage and the output voltage, i.e., the voltage across the load resistor of 1 kilo-ohm, as shown in figure (1b).

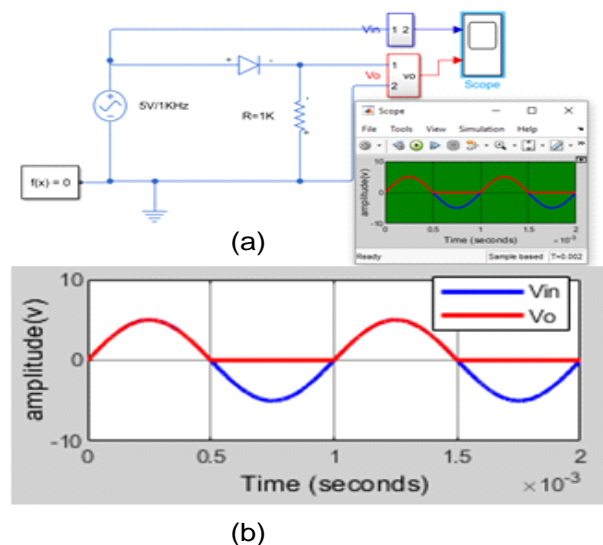


Fig. 1: Simulation Half-Wave Rectifier Circuit Diagram and Simulation Results

2.1.2 Full-wave rectifier

Diodes are used in full-wave rectification, and the circuit that performs full-wave rectification is known as a full-wave rectifier circuit, which includes a bridge rectifier. The bridge rectifier circuit was built using Simulink as shown in figure (2a), which includes a bridge rectifier and a load resistor with a value of 100ohms, as well as a signal generator. A test signal with an amplitude of 5 volts and a frequency of 1 kilohertz was applied to the input of the circuit shown in Figure (2a). After adjusting the parameters of the elements and simulating the circuit, the simulation results were obtained, which include the input voltage and the output voltage, i.e., the voltage across the load resistor of 100ohms, as shown in Figure (2b).

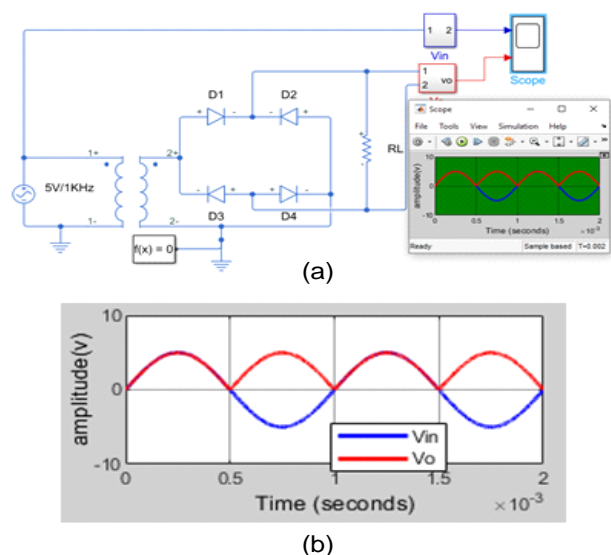


Fig. 2: Simulation Full-Wave Rectifier Circuit Diagram Simulation Results

2.1.3. Voltage regulator:

Diodes are used to regulate voltage, and when the input signal is positive, the diode is in a forward bias state and the input voltage is approximately equal to the output voltage. The circuit that performs this function is known as a voltage regulator circuit, which was built using Simulink as shown in Figure (3a). The circuit includes a diode, a resistor with a value of 1 kilo-ohm, and an AC power supply with an amplitude of 5 volts and a frequency of 1 kilohertz. After simulating the voltage regulator circuit, the simulation results were obtained,

which include the input and output voltages, as shown in Figure (3b). If the diode is reversed in the circuit shown in Figure (3a), the circuit becomes as shown in Figure (4a), which represents the voltage regulator circuit in the reverse bias state. After adjusting the circuit elements and simulation parameters, the simulation results were obtained, as shown in Figure (4b).

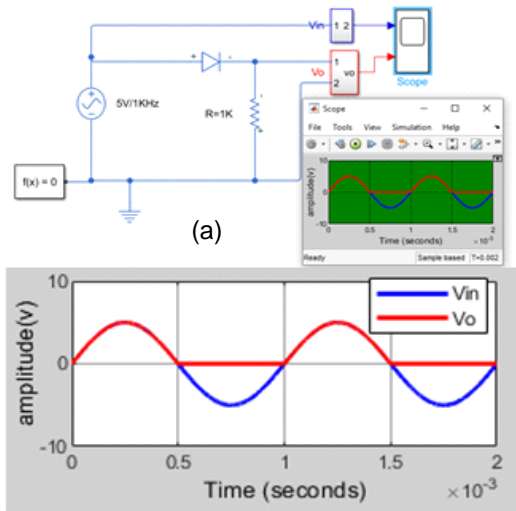


Fig. 3: Simulation Voltage Regulator Circuit Diagram Simulation Results Sequence limiter in case of frontal bias

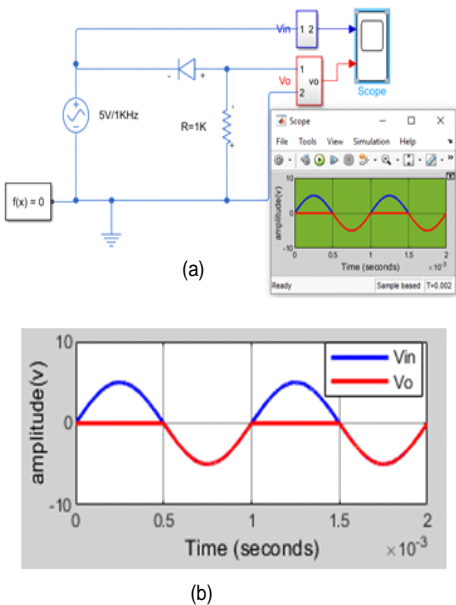


Fig. 4: Simulation Voltage Regulator Circuit Diagram Simulation Results Sequence limiter in case of frontal bias

2.1.4. Voltage limiter

Diodes are used as voltage limiters, and the circuit that performs this function was built using Simulink as shown in figure (5a). The circuit includes a diode, a resistor with a value of 1 kilo-ohm, and an AC power supply with an amplitude of 5 volts and a frequency of 1 kilohertz. After simulating the voltage limiter circuit, the simulation results were obtained, which include the input and output voltages, as shown in Figure (5b). If the diode is reversed in the circuit shown in Figure (5a), the circuit becomes as shown in Figure (6a), which represents the voltage limiter circuit in the reverse bias state. After adjusting the circuit elements and simulation parameters, the simulation results were obtained, as shown in Figure (6b).

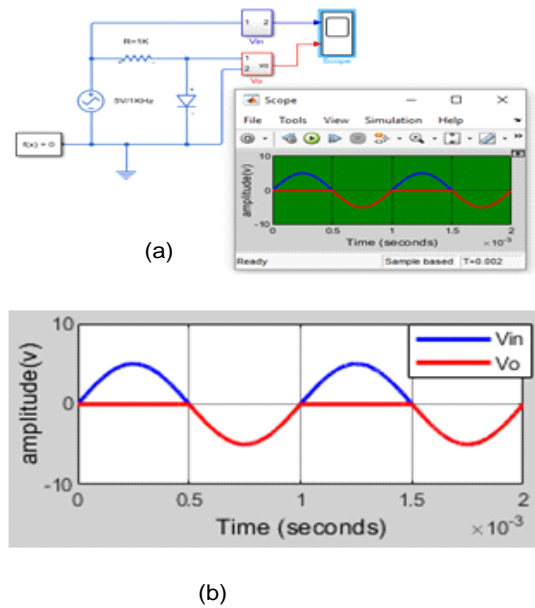


Fig. 5: Parallelism limiter in case of forward bias

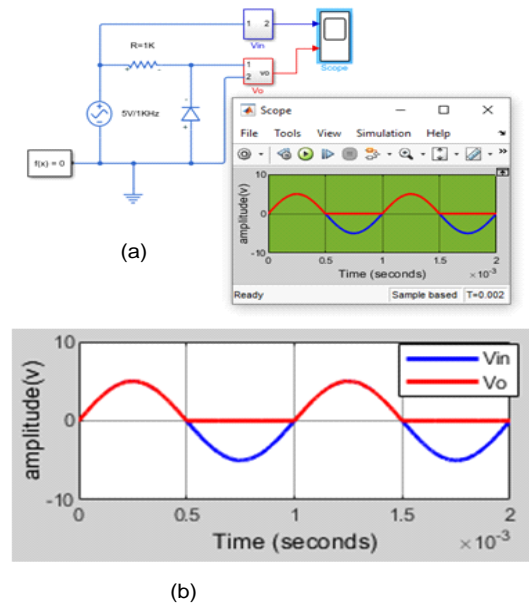
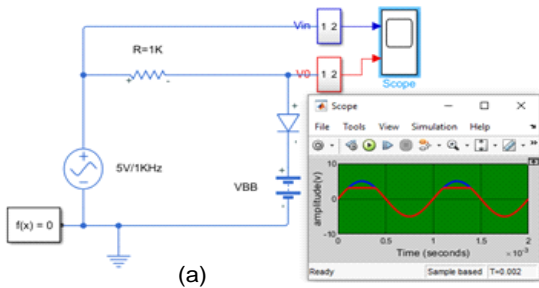


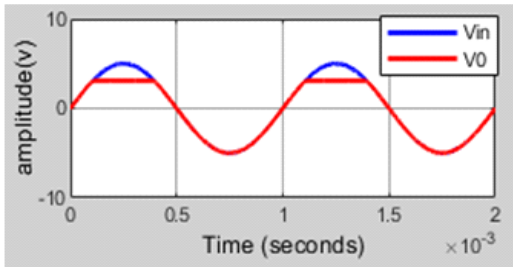
Fig. 6: Simulation of a parallel limiter in case of reverse bias, including the circuit diagram and simulation results.

2.1.5. Biased voltage limiter

Another application of diodes is a biased voltage limiter circuit, which was built using Simulink as shown in Figure (7a). The circuit includes a diode, a resistor with a value of 1 kilo-ohm, and an AC power supply with an amplitude of 5 volts and a frequency of 1 kilohertz. After simulating the biased voltage limiter circuit, the simulation results were obtained, which include the input and output voltages, as shown in Figure (7b). If the diode is operated in the reverse bias state, as shown in the circuit in figure (7a), the circuit becomes as shown in figure (8a), which represents the biased voltage limiter circuit in the reverse bias state. After adjusting the circuit elements and simulation parameters, the simulation results were obtained, as shown in Figure (8b).

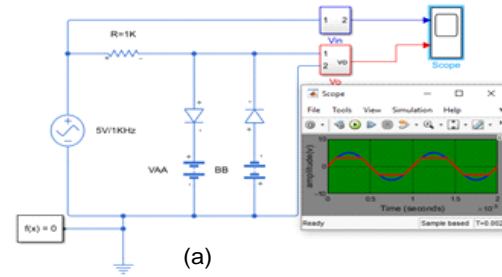


(a)

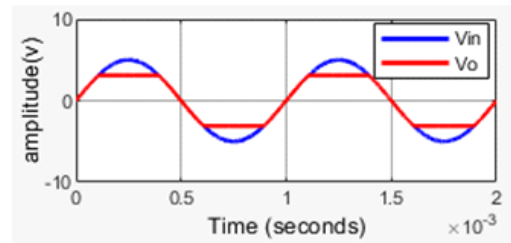


(b)

Fig.7: Simulation of a forward-biased parallel limiter, including the circuit diagram and input/output signals.

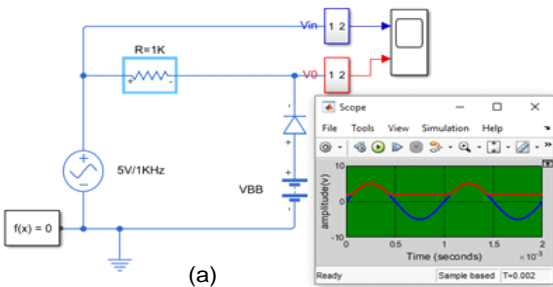


(a)

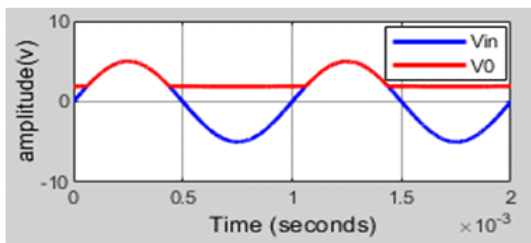


(b)

Fig.9: Simulation of a dual parallel-biased limiter, including the circuit diagram and input/output signals.



(a)



(b)

Fig.8: Simulation of a reverse-biased parallel limiter, including the circuit diagram and input/output signals.

2.1.6. Dual-biased voltage limiter

Another application of diodes is a dual-biased voltage limiter circuit, which was built using Simulink as shown in Figure (9a). The circuit consists of two diodes, two 5-volt batteries, a resistor with a value of 1kohms, and a signal generator. After adjusting all the circuit elements and simulation parameters, the simulation results were obtained, as shown in Figure (9b).

3. Operational amplifiers Basic Operation

Op-Amp is an integrated circuit that uses external voltage to amplify the input through a very high gain, the processing amplifier consists of a direct-gain amplifier with a large gain. An additive feeder to control its properties is used to accomplish different linear functions and some nonlinear functions. analog electronics uses. External components are used to control the characteristics of the operational amplifier circuit, including its gain, input and output impedance, bandwidth, etc. negative feedback, therefore manufacturing variations or temperature factors have little impact on the operating amplifier itself. Operational amplifiers were utilized in a variety of linear, non-linear, and frequency-dependent circuits in the first analog computers to perform mathematical operations. [6]

Because of their adaptability, op-amps are a common component in analog circuits. When negative feedback is employed, external components gain, input and output impedance, bandwidth, and other characteristics of an operational amplifier circuit. Temperature coefficients and variance-dependent manufacturing processes are mostly out of the operational amplifier's direct control [7, 8].

With their widespread application in a wide range of consumer, commercial, and scientific products, operational amplifiers are among the most popular electronic devices available today. While many conventional IC operational amplifiers cost only a few cents on modest manufacturing scales, some integrated or hybrid operational amplifiers with particular performance criteria may cost over US\$100 in small numbers. Operational amplifiers can be used as standalone devices or as parts of more intricate integrated circuits. on its own. [5, 6].

4. Modelling and Simulation of Op-Amp Circuits Applications

This work implements and simulates operational amplifier circuits using Simulink. These circuits are working as an inverter, non-inverter, summer, subtractors, integrators, and differentiators, as well as active filters such as low pass filter (LPF), high pass filter (HPF) and band pass filter (BPF) circuits. These implement and simulate circuits are as clarified in the following points:

4.1. Inverting Op-Amp Circuit

The inverting op-amp circuit model is implemented using Simulink as shown in Figure 10

R = 1K ohm and C = 0.2 uf are the values selected for the circuit. Then, apply a voltage of 2 V peak to peak and a frequency of 1 KHz at the circuit's input. After that scene, all the machinery and simulation Parameters. The displayed achieved simulation result is represented on the scope as shown in Fig.10

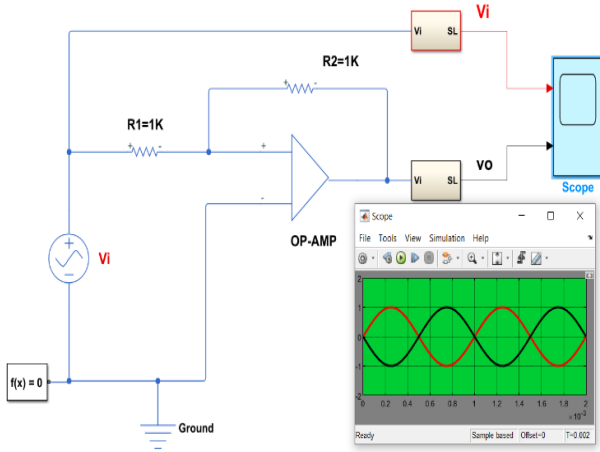


Fig.10: Simulation Inverting Circuit Diagram of an Op-Amp and Simulation Results.

4.2. Non-Inverting Op-Amp Circuit

Contracted using Simulink as illustrated in Figure 11. The gain is given by $1+R2/R1$, and with chosen t values of $R1=1K$ Ohm and $R2=1K$ Ohm. Then applied at the input of the circuit input voltage 2V peak-to-peak and with the frequency of 1 KHz. After that set the simulation and equipment parameters of a non-inverter circuit and then the realized simulation result is displayed on the scope as shown in Fig.11.

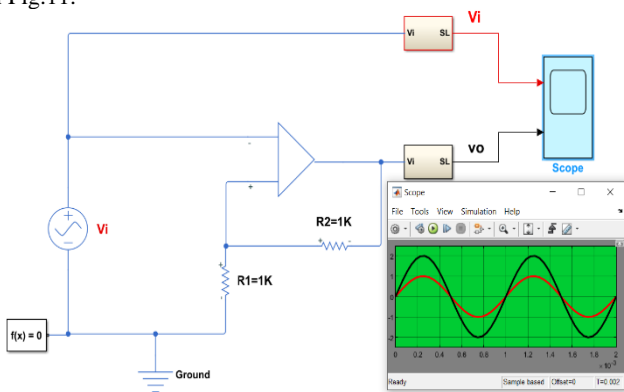


Fig11: Simulation Non-Inverting Circuit Diagram of an Op-Amp and Simulation Results.

4.3. Summing Op-Amp Circuit

An op-amp circuit model working as summer is implemented using Simulink as illustrated in Figure 12. 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 1 KHz after that set the simulation equipment parameters of the simulation circuit. After that, the apprehended simulation result is displayed on the scope as shown in Fig. 12.

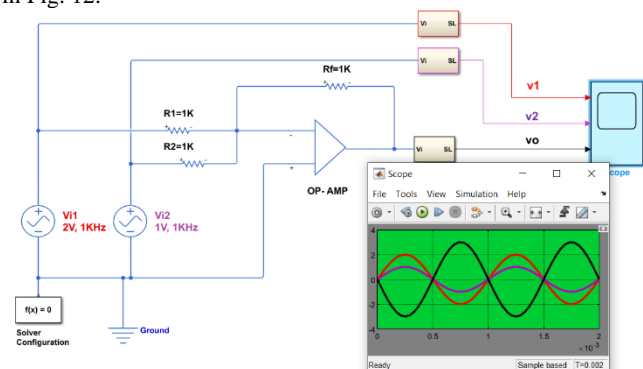


Fig.12: Simulation Summer Circuit diagram of an Op-Amp and Simulation Results.

4.4. Subtractor Op-Amp Circuit

Figure 13 shows how Simulink was used to create the circuit model of an op-amp acting as a subtractor. 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 1 KHz each. After implementation of the simulation circuit setting, all the simulation and equipment parameters of the simulation circuit and then the apprehended simulation result are displayed as shown in Fig. 13.

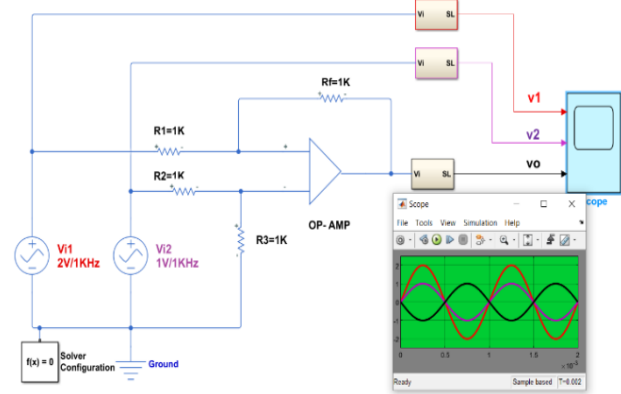


Fig. 13: Simulation Subtractor Circuit Diagram of an Op-Amp and Simulation Results.

4.5. Integrator Op-Amp Circuit

The integrator op-amp circuit model is constructed using Mat Simulink as shown in figure 14. The values of the circuit are chosen to be $R=1K$ Ohm and $C=0.2\mu f$. Then applied at the input of the circuit input voltage 2V peak-to-peak and with the frequency of 1 KHz. After that setting, all the simulation and equipment parameters of the simulation circuit and then the achieved simulation result are displayed on the scope as represented in Fig. 14.

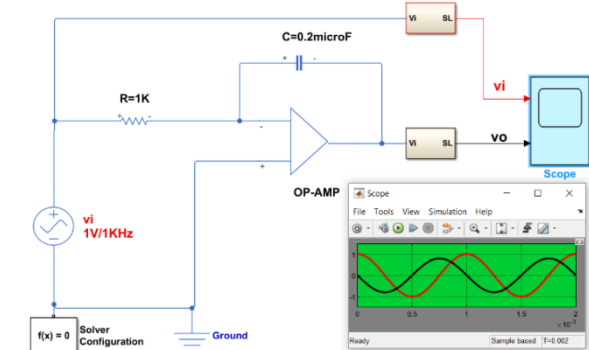


Fig. 14: Simulation Integrator Circuit Diagram of an Op-Amp and Displayed Simulation Results.

4.6. differential Op-Amp Circuit

The differential op-amp circuit model is implemented using Simulink as shown in Figure 15.

$R = 1K$ ohm and $C = 0.2$ uf are the presumptive values for the circuit. Then, apply an input voltage of 2 V peak-to-peak and a frequency of 1 KHz to the circuit's input. After that setting all the simulation and equipment parameters of the simulation circuit. Then the obtained simulation result is displayed on the scope as represented in Fig.15.

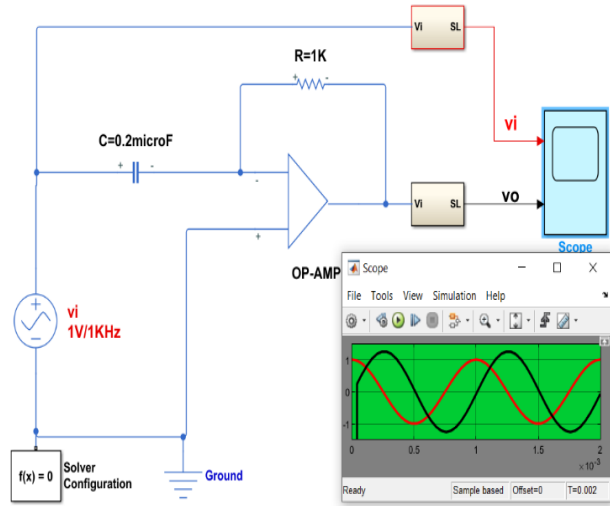


Fig. 15: Simulation differentiator Circuit diagram of an Op-Amp and Displayed Simulation Results

4.7. Simulation of an Active 2nd Order Filter

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

2nd Order Low Pass Filter

The 2nd order LPF circuit model is implemented using Simulink as shown in Fig.16. With the cut-off frequency of 1 KHz and values of the filter elements are $R1=1K\Omega$, $R2=2.414K\Omega$, $C1=160nF$ and $C2=66nF$. Next, a 2V peak-to-peak sinusoidal signal with a frequency range of 100 Hz to 4000 HKz was applied to the circuit's input. setting up the simulation circuit's various simulation parameters following that Then the obtained simulation result is clarified the frequency response of the 2nd-order LPF as represented in Fig. 17.

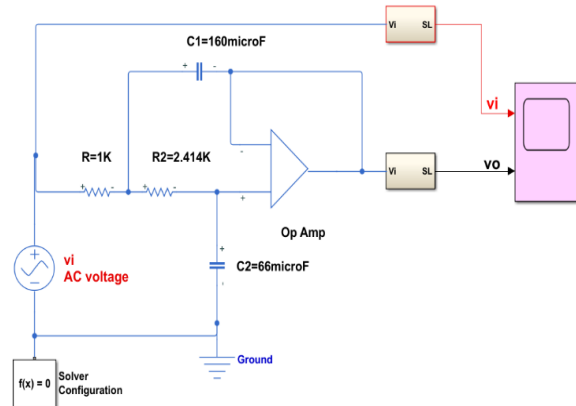


Fig.16: Simulation Circuit Model of 2nd Order Low Pass Filter

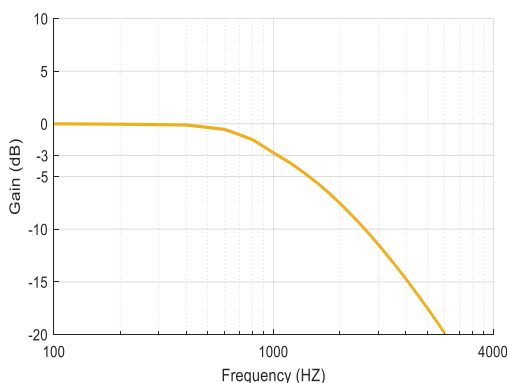


Fig. 17: Frequency Response of 2nd Order Low Pass Filter

5. Second Order High Pass Filter

The 2nd order high pass filter (HPF) circuit model is implemented as shown in Fig. 18. Using Simulink by replacing the resistances, $R1$ and $R2$ with capacitors $C1$ and $C2$ and capacitors $C1$ and $C2$ with resistances $R1$ and $R2$ in the LPF circuit shown in Fig.7. After that applied, A 2V peak-to-peak sinusoidal signal with a frequency range of 100 Hz to 4000 kHz is applied to the circuit's input. The simulation circuit has been run once all the simulation parameters have been established. and running the circuit. Then the obtained simulation result is clarified the frequency response of the 2nd-order LPF as represented in Fig. 19

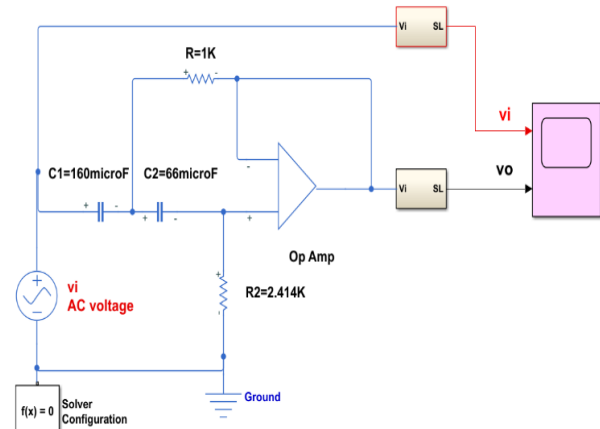


Fig. 18: Simulation Circuit Model of 2nd High Filter

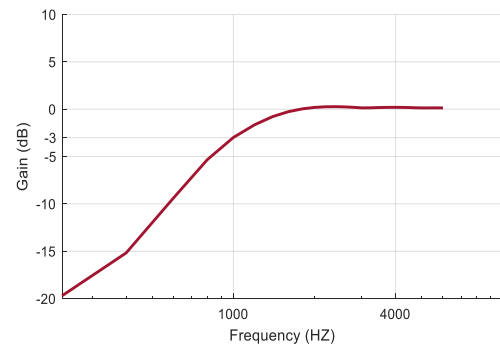


Fig. 19: Frequency Response of 2nd Order High Pass Filter

6. Band Pass Filter

BPF can be implemented by connecting the LPF circuit with the HPF circuit series using the Simulink tool as shown in Fig.11. While the cut-off frequency of the LPF is 3 KHz and the cut-off frequency of HPF is 1 kHz. The values of the filter elements are $R1= R3=1K\Omega$, $R2=R4=2.414K\Omega$, $C1=53.3nF$, $C2=22nF$, $C3=160nF$ and $C4=66 nF$. Then applied at the input of the filter 2V peak-to-peak sinusoidal signal and with a frequency range from 100Hz to 4000HKz. After setting all the simulations the frequency response of the BPF as shown in Fig. is used to illustrate the simulation result, while the parameters of the BPF simulation are shown. 12.

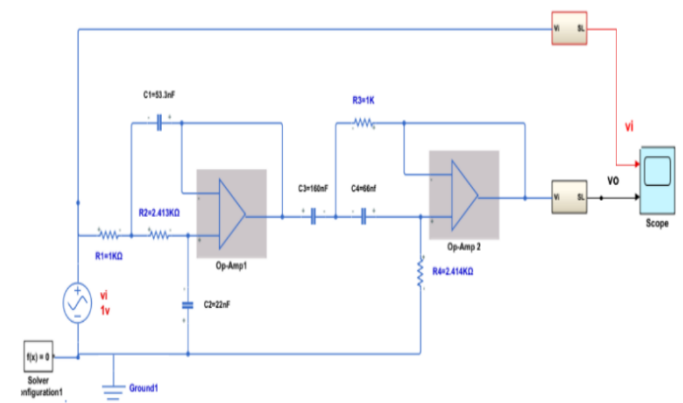


Fig. 20. Simulation Circuit Model of Band Pass Filter

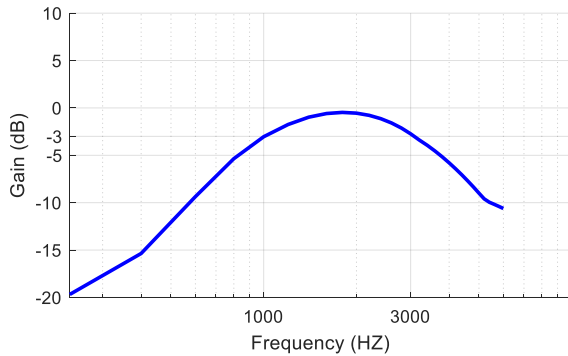


Fig 21. Frequency Response of BandPass Filter.

7. Conclusion

Diodes are electronic components that exhibit a range of benefits and enjoy a wide variety of applications in technical and engineering fields. In order to explore and analyze some of these applications, scientific software tools such as MATLAB and Simulink version 2019a were utilized to simulate the behaviour of diode circuits. The simulations included the behaviour of diode circuits such as half-wave and full-wave rectifiers, voltage regulators, and voltage limiters. The results obtained from these simulations were found to agree with theoretical expectations, thereby confirming the validity of the theoretical models. These simulations demonstrate the important role that scientific software plays in validating theoretical models and facilitating the design of electrical, electronic, and digital circuits before their practical implementation.

Operational amplifiers are fundamental electronic devices that find wide applications in various fields of physics and engineering. The main operational amplifiers applications, such as buffer, inverter, non-inverter, summer, subtractor, differentiator, integrator, and active low pass, high pass, and bandpass filters of 2nd order have been implemented using Simulink simulations, which provide a powerful tool for designing and analyzing electronic circuits. The simulations demonstrate the effectiveness of computer-aided design tools and their ability to validate theoretical models, which saves time and cost in the design and implementation phases of electrical, electronic, and digital circuits. Moreover, such simulations can be used to explore and analyze the behaviour of physical systems, including operational amplifier circuits, without the need for physical implementation.

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