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19EAC284 Electronic Circuits II Lab

Project Title

Two Way Active Cross-Over

Group-6

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LIST OF FIGURES		
Fig.No.	Name	Page No.
1	Dual Op-amp	6
2	Frequency response curve	8
3	Spice diagram	9
4	Input Waveform	10
5	Low Out	10
6	High Out	11
7	Frequency response	11
8	Hardware Circuit	12
9	Low Out (High Input)	15
10	High Out (High Input)	15
11	Low Out (Low Input)	16
12	High Out (Low Input)	16
13	Figure 13. Linkwitz-Riley 4th Order frequency response curve	19

ABSTRACT

The Two Way Active Crossover using Op Amp project is designed to separate an audio signal into two separate frequency ranges, and send them to the appropriate speakers.

Unlike passive crossovers, which rely on passive components like capacitors and inductors, active crossovers utilize electronic circuits and amplifiers to accomplish the frequency separation.

The crossover uses op-amps to create high-pass and low-pass filters that can be independently adjusted to achieve the desired crossover frequency. The circuitry also includes gain stages to ensure that the signal levels are appropriate for driving the speakers.

Active crossovers advantages:

- Better frequency response
- More flexibility
- Less distortion

Active crossovers disadvantages:

- Higher cost
- More complex
- More power consumption

This project is an excellent introduction to audio electronics and op-amp circuits, and can be easily modified for different crossover frequencies and configurations.

INTRODUCTION

The Two-Way Active Crossover project using Op Amp is an interesting venture into the field of audio electronics. This project involves designing and constructing a circuit that effectively separates an audio signal into two distinct frequency ranges and routes them to separate speakers. What makes this crossover "active" is the utilization of operational amplifier (op-amp) circuits to create high-pass and low-pass filters, which can be independently adjusted to achieve the desired crossover frequency.

In any audio system that incorporates multiple speakers, such as a stereo system or home theatre setup, a crossover plays a vital role. Its purpose is to divide the audio signal into different frequency ranges and direct each range to the appropriate speaker. For instance, in a typical two-way speaker system, the woofer is responsible for handling the lower frequencies, while the tweeter takes care of the higher frequencies. The crossover circuit ensures that the correct frequencies are delivered to the respective speakers, enabling them to perform optimally in their designated frequency range.

There are two primary types of crossovers: passive and active. Passive crossovers utilize passive components like capacitors and inductors to create the necessary frequency filters. On the other hand, active crossovers employ active components such as op-amps to accomplish the same task. Active crossovers are often favoured over passive crossovers due to their ability to offer greater control over the frequency response and facilitate easier adjustments.

In this project, we aim to create a Two-Way Active Crossover by employing a low-pass filter and a summing amplifier circuit with a targeted cut-off frequency of 3.5 kHz. This specific cut-off frequency has been chosen to efficiently split the audio signal into two distinct frequency ranges, optimizing the performance of the connected speakers.

To begin the project, we need to carefully select the appropriate op-amp and passive components based on the desired specifications and frequency response requirements. The op-amp will serve as the core component responsible for implementing the high-pass and low-pass filters. The low-pass filter will allow frequencies below the cut-off point to pass through, while attenuating higher frequencies. And these frequencies below the cut-off point is removed from the input signal using a summing amplifier circuit to obtain frequencies above the cut-off point .

Once the components are selected, according to the given values the circuit design phase starts. This involves creating a schematic diagram that depicts the connections and configuration of the op-amp, resistors, capacitors, and other necessary components.

Following the circuit design, the next step involves prototyping and building the actual circuit on a breadboard. After successfully constructing the circuit, testing and fine-tuning become crucial. Audio signals of various frequencies can be fed into the circuit, and the output from each channel is analysed using an oscilloscope.

Adjustments are made to the resistors and capacitors in the filters to achieve the desired crossover frequency and ensure a smooth transition between the frequency ranges.

Finally, we can evaluate circuit's performance by connecting the speakers to the respective outputs and playing audio content across a wide range of frequencies.

In conclusion, the Two-Way Active Crossover using Op Amp project presents an opportunity to delve into the fascinating world of audio electronics. By designing and constructing a circuit that utilizes op-amp-based active filters, we can achieve precise frequency separation and optimize the audio performance of a multi-speaker system. This project combines theoretical knowledge, practical circuit design skills, and audio testing to create a functional and efficient active crossover.

LITERATURE SURVEY

Analog, Active Crossover Circuit for Two-Way Loudspeakers

An active crossover circuit that can be used to divide an audio signal into two frequency bands for a two-way loudspeaker system.

The document covers the following topics:

- Overview of the analog, active crossover circuit
- Design considerations for the analog, active crossover circuit
- Components used in the analog, active crossover circuit
- Applications of the analog, active crossover circuit

The document also includes a number of figures and tables that illustrate the features and capabilities of the analog, active crossover circuit.

The analog, active crossover circuit is a simple and effective way to divide an audio signal into two frequency bands for a two-way loudspeaker system.

The circuit uses a number of passive components, such as resistors and capacitors, to divide the audio signal.

The circuit can be adjusted to provide a variety of crossover slopes, which can be used to optimize the sound quality of the loudspeaker system.

The circuit is relatively inexpensive to build, and it can be easily implemented in a variety of loudspeaker systems.

Overall, the document provides a comprehensive overview of an analog, active crossover circuit for two-way loudspeaker systems. The document is well-written and easy to understand, and it includes a lot of information that would be useful to anyone who is considering using an analog, active crossover circuit in their loudspeaker system

Circuit Design: Two Way Active Audio Crossover Filter

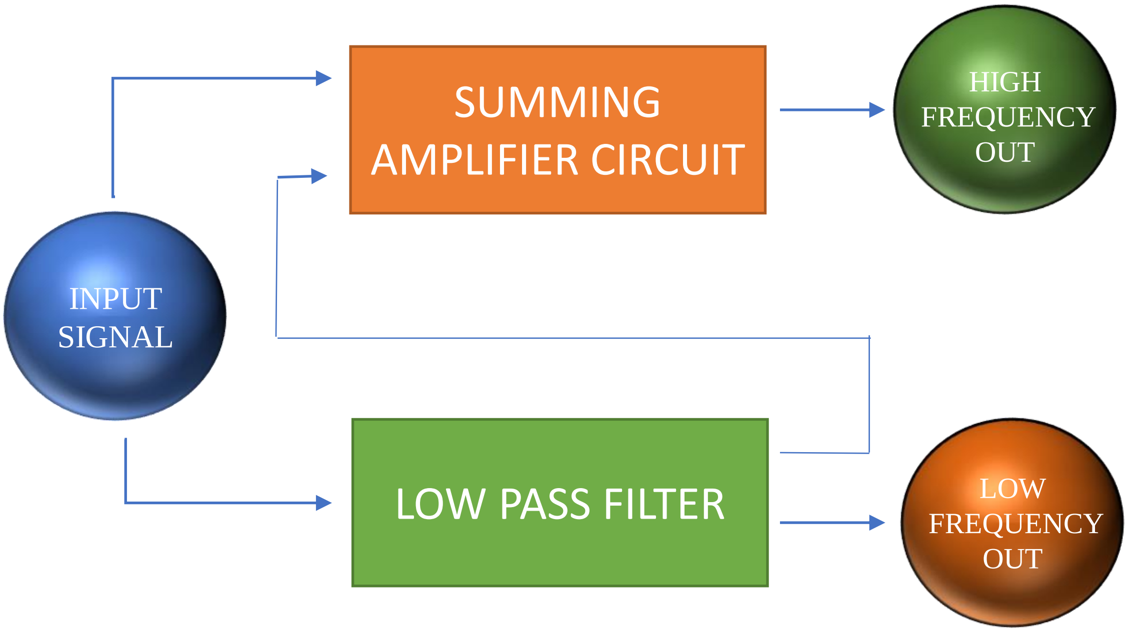
The document discusses the design of a two-way active audio crossover filter. A two-way active audio crossover filter is a type of electronic filter that is used to divide an audio signal into two frequency bands, typically a low-frequency band and a high-frequency band. The filter is typically used in two-way loudspeaker systems to ensure that each loudspeaker is only reproducing the frequencies that it is designed to reproduce.

The document discusses the design considerations for two-way active audio crossover filters, including the frequency range of the loudspeaker system, the crossover frequency between the low-frequency band and the high-frequency band, the crossover slope, the type of filter topology to be used, and the components to be used in the filter.

The document then describes a specific two-way active audio crossover filter that uses a 4th-order Linkwitz-Riley crossover topology. This topology provides a smooth and gradual transition between the frequency bands, which is desirable for high-quality audio applications. The filter uses OPA1602/1604 low-noise operational amplifiers, which provide high gain and low distortion. The circuit is designed to operate with an input signal level of +4dBu, which is suitable for professional audio applications. The circuit is housed in a compact, 4-layer PCB that is easy to assemble.

The document concludes by providing a list of resources for further reading on the topic of two-way active audio crossover filters.

BLOCK DIAGRAM



The frequency may be changed by increasing or decreasing resistor / capacitor values.
•Increasing capacitance or resistance - Reduces frequency
•Doubling the capacitance or resistance halves the frequency
•Reducing capacitance or resistance - Increases frequency
•Halving the capacitance or resistance doubles the frequency

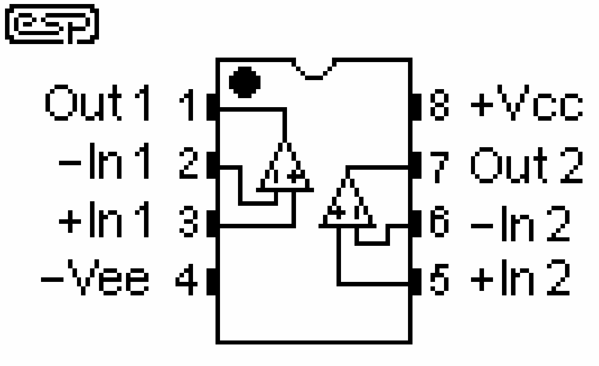


Figure 1. DUAL OP-AMP

We are using Standard Dual op-amp whose pinout diagram is given on the left
Formulae for frequency is $f = 1 / (2\pi \times R \times C)$

The circuit consists of a 2 consecutive integrator circuit and a summing amplifier using op-amp.

An integrator acts a lowpass filter for frequencies below the cut-off frequency given by the equation:

$$f = \frac{1}{2\pi RC}$$

Where,

R → Feedback Resistor

C → Capacitance

Through various statistics it was found that 3.5KHz was the best cross over frequency for two-way active cross over. As a result, we obtain the required values for R and C as 6.6KΩ and 6.8nF respectively.

The few statistics under which 3.5KHz is chosen are:

- Driver Characteristics:

The selection of the crossover frequency is influenced by the frequency response and capabilities of the loudspeaker drivers. In many cases, drivers such as tweeters and mid-range drivers have optimal performance within certain frequency ranges. By setting the crossover frequency around 3.5 kHz, it allows for efficient integration between the drivers and ensures that each driver operates within its optimal frequency range.

- Directivity Control:

The crossover frequency can impact the directivity and dispersion characteristics of the loudspeaker system. Higher crossover frequencies tend to have narrower directivity patterns, which can help in achieving better control over the sound coverage and avoiding interference between drivers. A 3.5 kHz crossover frequency strikes a balance between achieving directivity control and smooth integration of the drivers.

- System Design Considerations:

The overall system design and intended application also play a role in determining the crossover frequency. For example, in two-way loudspeaker systems, where there are only two drivers (e.g., woofer and tweeter), a crossover frequency around 3.5 kHz can provide effective separation between the low and high-frequency bands. This frequency range is commonly used for compact and medium-sized loudspeaker systems.

- Performance Trade-offs:

The choice of crossover frequency involves trade-offs between various factors, such as driver size, driver response, power handling, and distortion characteristics. The specific requirements of the system and the desired acoustic performance guide the selection process. 3.5 kHz may be chosen to balance the power handling capabilities of the drivers, the need for smooth frequency response, and minimizing distortion and intermodulation effects.

An integrator circuit as mentioned acts a low pass filter for all frequency below cut-off frequency and it simply acts a inverting amplifiers. It is noted that a small loss happens if the gain is set to be unity hence, we set a gain >1 by selecting the required resistor value, using the equation:

$$Gain = \frac{Rf}{R1}$$

A consecutive integrator is kept for correcting the phase shit as well as to make sure any noise which where not detected due low amplitude gets filtered out.

The first filtered signal is taken as input with the original signal in a non-inverting summing amplifier to get the high frequency components of the original signal.

$$-V0 + Vin = Vhigh$$

Hence we get two outputs one low frequency component consisting all frequencies below 3.5KHz only and the other a high frequency consisting all frequencies above 3.5KHz alone.

Some frequencies will be seen on both sides as Crossover is not that smooth as depicted in the figure 2,

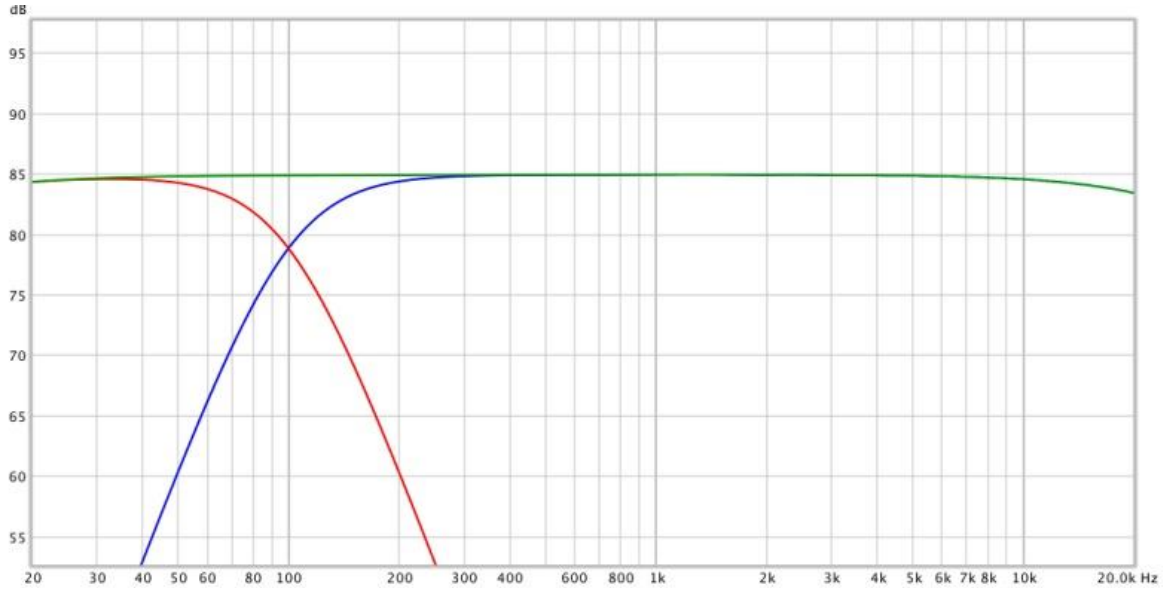


figure 2. Frequency response Curve

SIMULATION EXPERIMENTS

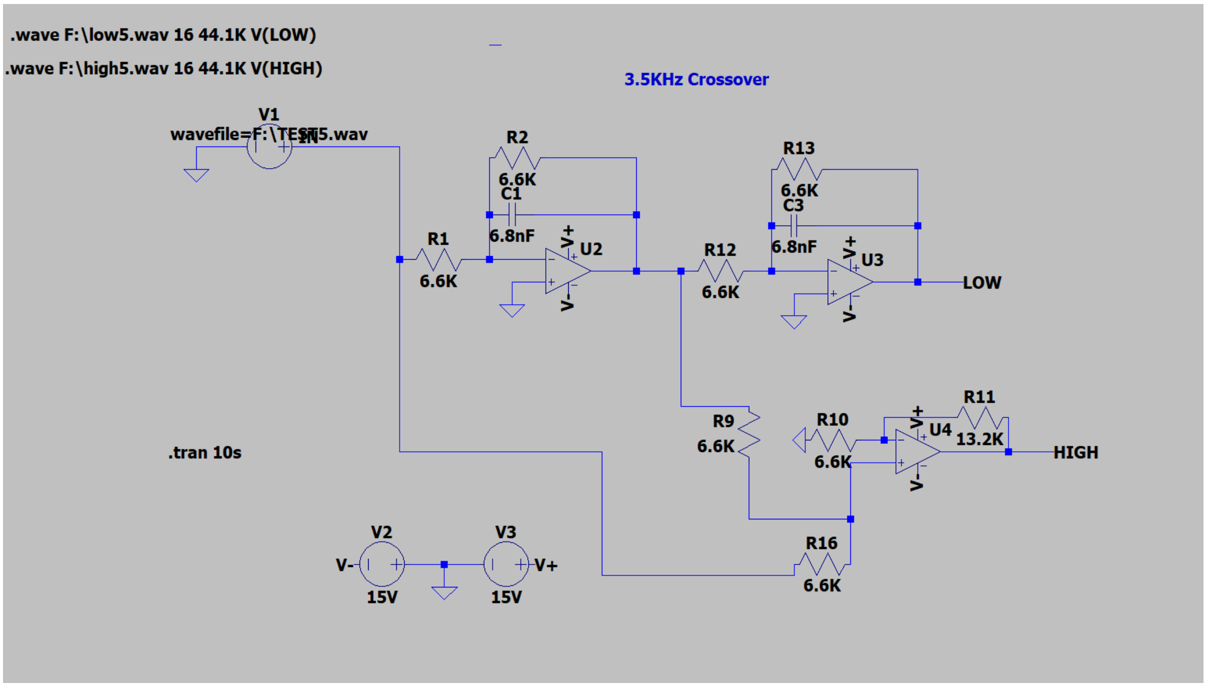


Figure 3. Spice Diagram

Design:

Taking, C=6.8nF

$$f = \frac{1}{2\pi RC} \Rightarrow 3.5KHz = \frac{1}{2\times3.14\times R\times6.8nF} \Rightarrow R = \frac{1}{2\times3.14\times3.5\times10^{3}\times6.8\times10^{-9}} \Rightarrow R = 6.6K\Omega$$

Working:

When a signal is introduced at the input side it enters the inverting terminal of the op amp containing the integrator circuit. the integrator circuits acts as an low pass filter, that is for all frequency components less than the cross over frequency (3.5KHz) of the input signal passes through as an amplified versions of their original form, and all the higher gets suppressed by getting it getting integrated and supressed there by obtaining the Low Output components of the signal. The low out signal has a phase shift of 180 which is removed by again passing through another integrator circuit of gain 1.
The input signal also enters the non-inverting terminal of the summing amplifier circuit op amp along with low output which containg only the lower frequency components with phase of 180. which results with only the high frequency components only at the output side.

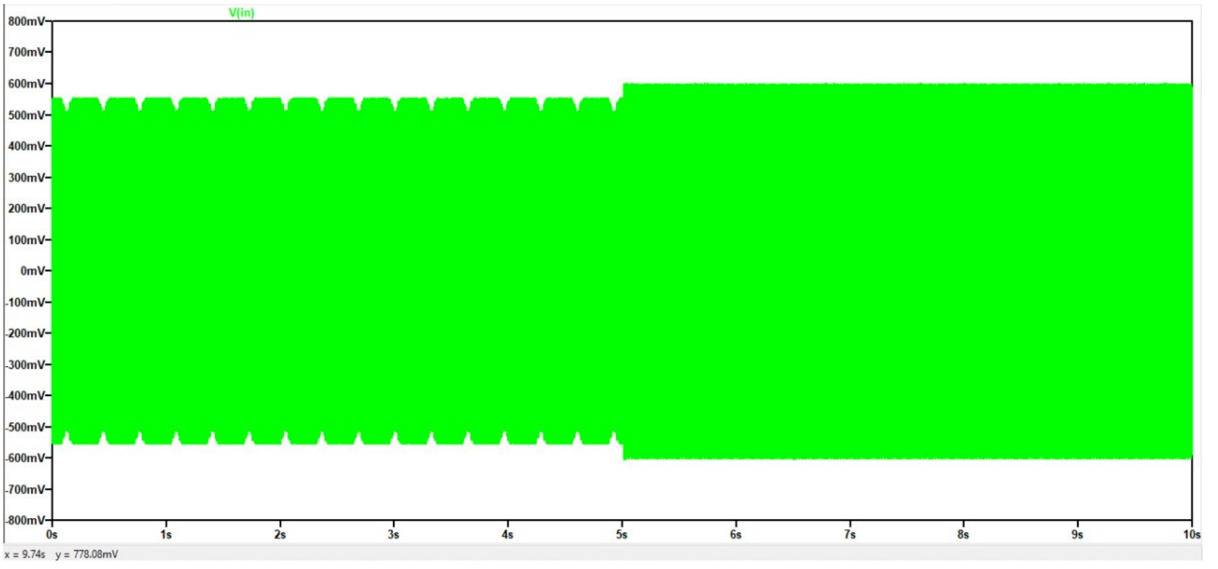


Figure 4. Input waveform, Its an audio signal whose 1 to 5 seconds is of frequency 500Hz & 5 to 10 seconds is of frequency 4500Hz

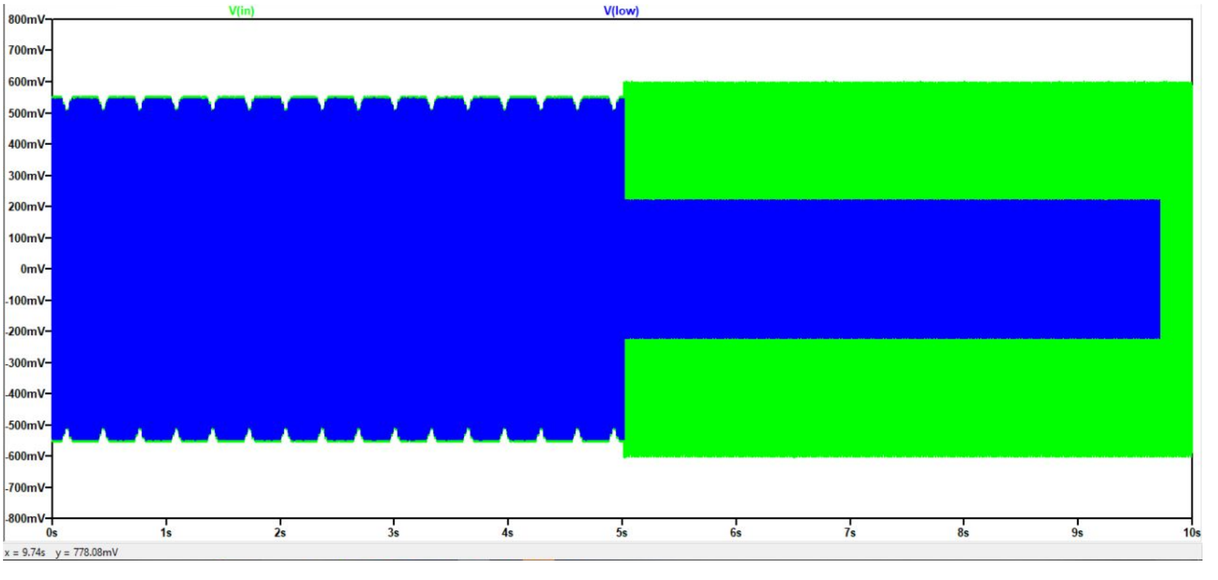


Figure 5. Output waveform at LOW were high frequency component is suppressed

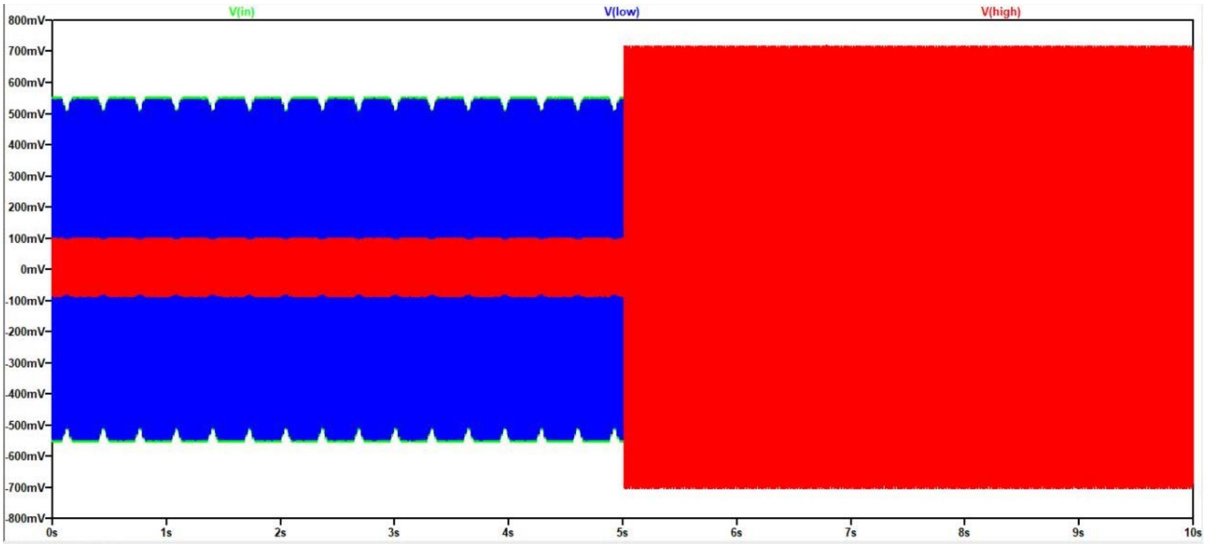


Figure 6. Output waveform at HIGH were low frequency component is suppressed

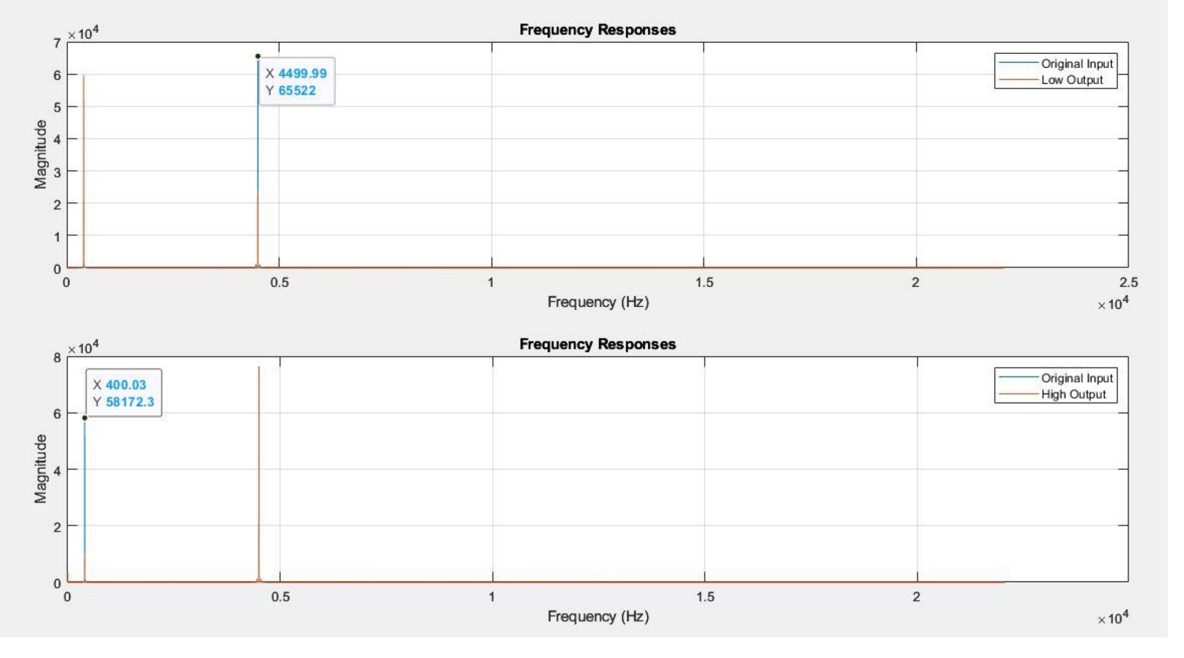


Figure 7. Frequency response using MATLAB showing the suppression of frequencies

HARDWARE EXPERIMENTS

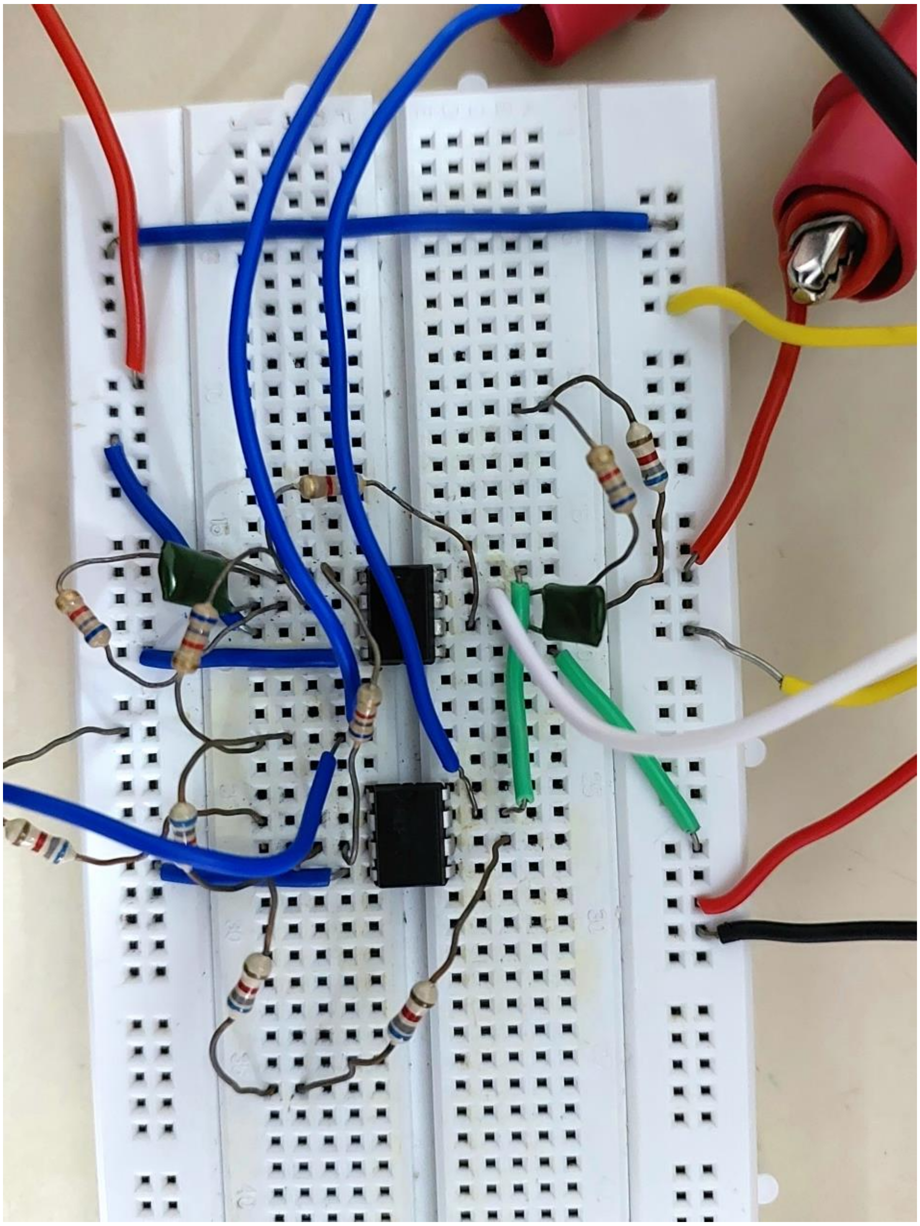


Figure 8. Hardware Circuit

COMPONENT USED

SL.NO.	COMPONENT	QUANTITY
1	DUAL OP-AMP	1
2	OP-AMP	1
3	CAPACITOR (6.8nF)	2
4	RESISTOR (6.6KΏ)	10
5	BREADBOARD	1
6	CONNECTING WIRES	As much as required

1) DUAL OP-AMP

A dual op-amp is an integrated circuit (IC) that contains two separate operational amplifiers within a single package. Each op-amp operates independently and has its own set of input and output pins. The dual op-amp is widely used in various electronic circuits where multiple amplifiers are required, offering advantages such as space-saving and convenience.

The operational amplifier, often referred to as an op-amp, is a versatile and essential component in analog electronic circuits. It is widely used for amplification, filtering, signal conditioning, and other signal processing applications. The op-amp has two input terminals, usually labeled as the inverting (-) and non-inverting (+) inputs, and one output terminal.

A dual op-amp typically comes in an 8-pin Dual Inline Package (DIP) or a surface-mount package. The two separate op-amps share a common power supply and ground pins, simplifying the circuit connections.

Some key features and advantages of using a dual op-amp include:

1. Space-saving: Since two op-amps are integrated into one package, it reduces the number of components needed on a PCB, saving space and simplifying circuit design.
2. Matching Characteristics: The op-amps within a dual package are designed to have similar characteristics, including input offset voltage, input bias current, and other specifications, ensuring better performance consistency.
3. Noise Reduction: By using a dual op-amp, potential noise coupling between two separate op-amp ICs is eliminated, leading to improved noise performance.
4. Cost-effectiveness: Using a dual op-amp can be more cost-effective than using two individual op-amp ICs, especially when considering space and packaging costs.

2) OP-AMP

An op-amp, short for operational amplifier, is a versatile integrated circuit used in analog electronic circuits. It amplifies and processes analog signals with high gain and high input impedance. Op-amps have two input terminals (inverting and non-inverting) and one output terminal. They are widely employed in various applications, including amplification, filtering, voltage following, and signal conditioning, making them a fundamental component in modern electronics.

3) CAPACITOR (6.8nF)

A capacitor is an electronic component that stores and releases electrical energy. The value "6.8nF" indicates the capacitance of the capacitor, which is 6.8 nanofarads. Capacitors are commonly used in electronic circuits for various purposes, such as filtering, coupling, timing, and energy storage. They are essential components in many electronic devices and play a crucial role in maintaining stable voltage levels and smoothing out fluctuations in electrical signals.

4) RESISTOR (6.6KΏ)

A resistor is an electrical component that limits or controls the flow of electric current in a circuit. The value "6.6KΏ" indicates the resistance of the resistor, which is 6.6 kilohms. Resistors are commonly used in electronic circuits to set specific currents, voltage levels, and to divide voltage in a circuit. They are one of the most basic and widely used components in electronics, and their resistance value determines the amount of current flowing through them according to Ohm's law (V = I * R).

5) BREADBOARD

Breadboard is a prototyping tool used in electronics to build and test circuits quickly and easily without soldering. It consists of a plastic board with a grid of holes and metal strips or clips underneath. The holes on the breadboard are connected in rows and columns, and each hole can hold a component's lead or wire.

One of the main advantages of using a breadboard is its reusability. Components can be easily inserted, moved, or removed from the board, allowing for rapid circuit modifications and design iterations. This makes breadboards ideal for testing and validating circuit designs before they are permanently soldered onto a printed circuit board (PCB).

6) CONNECTING WIRES

Connecting wires are essential components in electronic circuits used to establish electrical connections between various components, such as resistors, capacitors, diodes, transistors, and integrated circuits (ICs). These wires, often made of copper or aluminum, come in various lengths, colors, and gauges, and they serve as conductors to carry electrical signals and currents within a circuit.

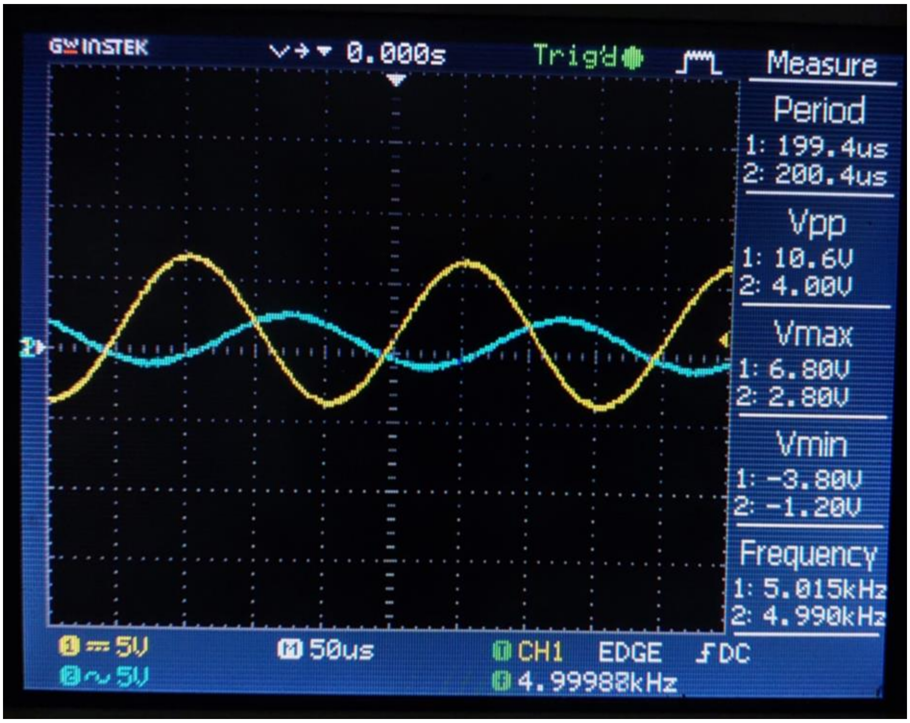


Figure 9. Output waveform at LOW OUT when a sin wave of frequency 5KHz and 10V peak to peak is passed as input

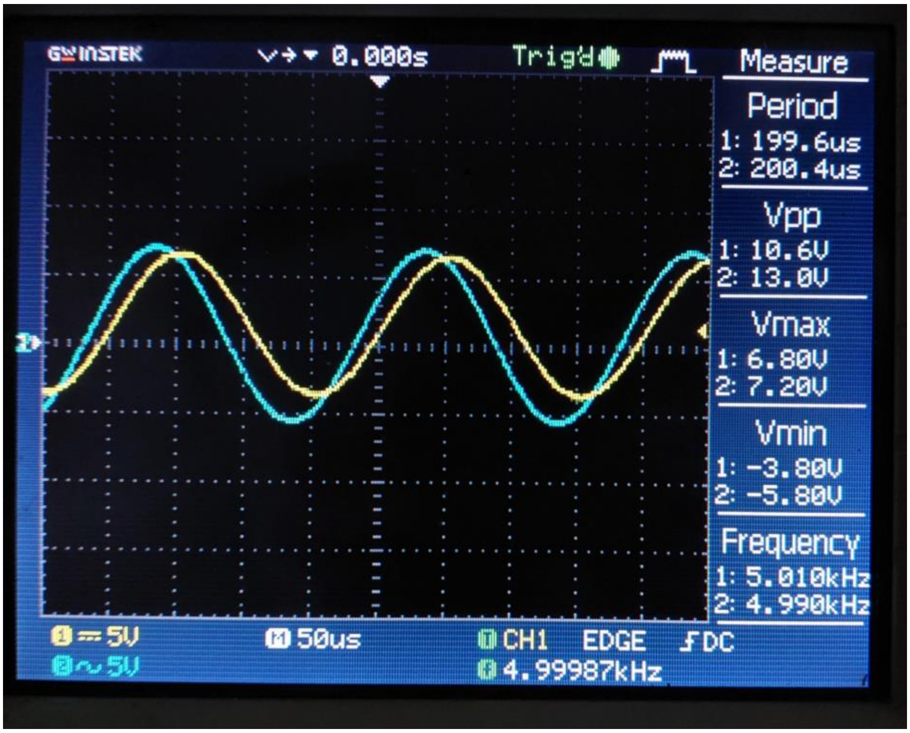


Figure10. Output waveform at HIGH OUT when a sin wave of frequency 5KHz and 10V peak to peak is passed as input

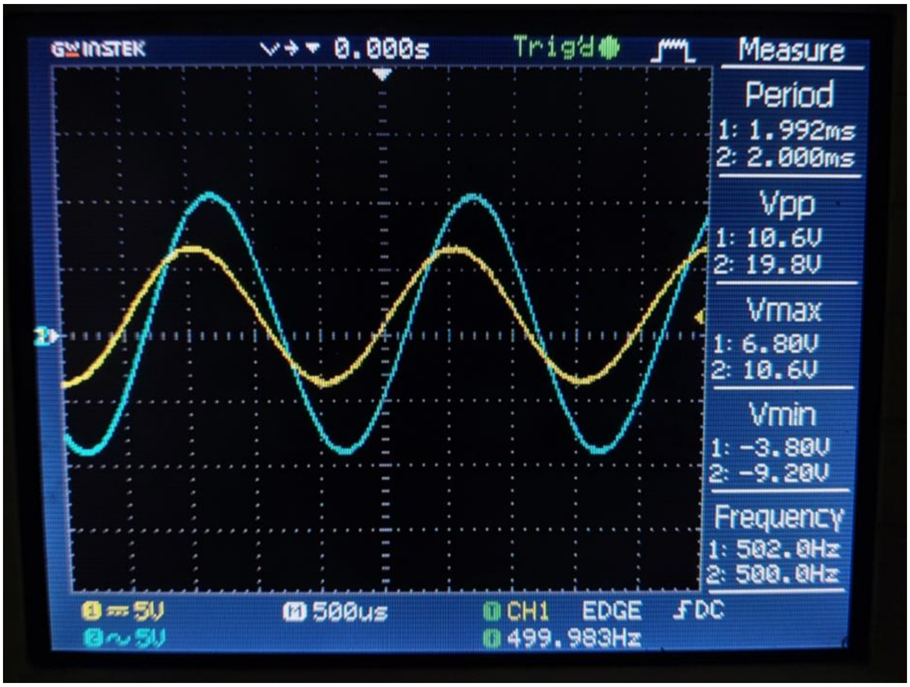


Figure 11. Output waveform at LOW OUT when a sin wave of frequency 500Hz and 10V peak to peak is passed as input

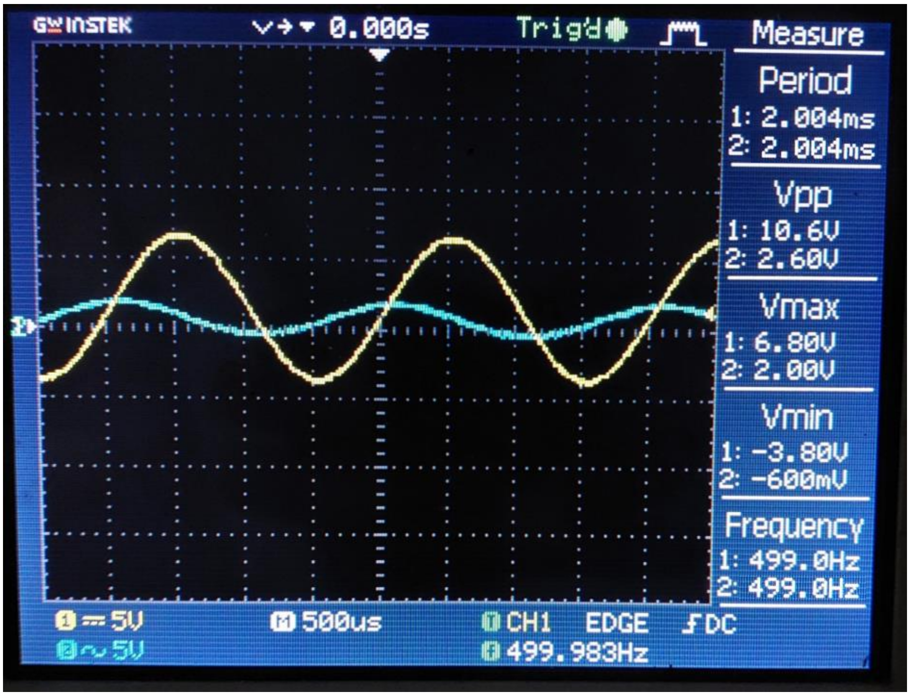


Figure 12. Output waveform at HIGH OUT when a sin wave of frequency 500Hz and 10V peak to peak is passed as input

CONCLUSION

In conclusion, the Two-Way Active Crossover project using Op Amp gives us a small look into the realm of audio electronics. By employing op-amp-based active filters, we have successfully designed and constructed a circuit capable of separating audio signals into distinct frequency ranges and directing them to their respective speakers. Through this project, we have gained insights into the details of crossover design and the critical role it plays in optimizing the performance of multi-speaker audio systems.

The use of active crossovers with op-amp circuits has proven to be advantageous, offering greater flexibility and control over the frequency response compared to passive crossovers. The ability to adjust the crossover frequency and tailor the audio output to specific speaker characteristics allows for a more customized and immersive audio experience.

We carefully selected components, designed the circuit, and fine-tuned the filters to achieve the targeted cut-off frequency of 3.5 kHz. Thorough testing and analysis of the circuit's performance with an oscilloscope ensured the precise functionality of the crossover.

The successful implementation of the Two-Way Active Crossover using Op Amp reinforces the significance of audio signal processing in delivering high-quality sound reproduction. This project deepens our understanding of op-amp-based filter design, circuit prototyping, and practical audio testing techniques.

As we connect the speakers to the outputs and listen to the audio content across a wide range of frequencies, the optimized performance of the multi-speaker system becomes evident. The smooth transition between frequency ranges and the accurate delivery of audio signals to their designated speakers create an immersive and enjoyable listening experience.

Overall, the Two-Way Active Crossover using Op Amp project has been a wonderful journey, blending theory and practice to achieve an efficient and effective audio solution. It exemplifies the exciting possibilities in the field of audio electronics and motivates us to continue exploring innovative approaches to optimize audio performance in various applications.

RECOMMENDATION

The problem faced in this project is that the Cross Over is not that smooth and low frequencies ends up entering the high frequency side while low frequency in high frequency side, this situation can be tackled if we are using a 4th-order Linkwitz-Riley crossover topology

Ie, A 4th-order Linkwitz-Riley crossover is a type of electronic filter that is used to divide an audio signal into two frequency bands. It is a type of filter that has a very steep roll-off, meaning that it quickly attenuates frequencies that are outside of the desired band. This makes it ideal for use in loudspeaker systems, as it ensures that each loudspeaker is only reproducing the frequencies that it is designed to reproduce.

The design of a 4th-order Linkwitz-Riley crossover is based on the following equation:

f = fc / (1 + (2^n * f / fc)^2)

where:

f is the frequency

fc is the crossover frequency

n is the order of the filter (in this case, 4)

This equation shows that the filter has a 24dB/octave roll-off, which means that the amplitude of the signal is reduced by 24dB for every octave that the frequency is increased.

The working of a 4th-order Linkwitz-Riley crossover can be explained as follows:

- The input signal is fed into the filter.
- The filter divides the signal into two frequency bands, a low-frequency band and a high-frequency band.
- The low-frequency band is passed to the low-frequency loudspeaker.
- The high-frequency band is passed to the high-frequency loudspeaker.
- The loudspeakers reproduce the frequencies that they are designed to reproduce.

4th-order Linkwitz-Riley crossovers are a popular choice for use in loudspeaker systems because they provide a smooth and gradual transition between the frequency bands. This is important for ensuring that the sound produced by the loudspeakers is accurate and natural.

Some of the advantages of using a 4th-order Linkwitz-Riley crossover:

- It provides a smooth and gradual transition between the frequency bands.
- It has a very steep roll-off, which ensures that frequencies that are outside of the desired band are attenuated.
- It is relatively easy to design and implement.

Here are some of the disadvantages of using a 4th-order Linkwitz-Riley crossover:

- It requires more components than some other types of filters.
- It can be more expensive than some other types of filters.

Overall, 4th-order Linkwitz-Riley crossovers are a good choice for use in loudspeaker systems where accurate and natural sound reproduction is important A 4th-order Linkwitz-Riley crossover gives smooth transitions by using a special type of filter design called a Butterworth filter. Butterworth filters are designed to have a smooth and gradual roll-off, which means that the amplitude of the signal is reduced gradually as the frequency is increased. This results in a smooth and natural transition between the frequency bands.

The specific design of a 4th-order Linkwitz-Riley crossover uses two Butterworth filters, one for the low-frequency band and one for the high-frequency band. The two filters are cascaded, which means that the output of the first filter is the input to the second filter. This results in a filter that has a very steep roll-off, which ensures that frequencies that are outside of the desired band are attenuated.

The smooth transitions of a 4th-order Linkwitz-Riley crossover are important for ensuring that the sound produced by the loudspeakers is accurate and natural. When the crossover is not smooth, it can cause audible artifacts, such as "notches" or "bumps" in the frequency response. This can make the sound unnatural and unpleasant to listen to.

Here is a graph that shows the frequency response of a 4th-order Linkwitz-Riley crossover:

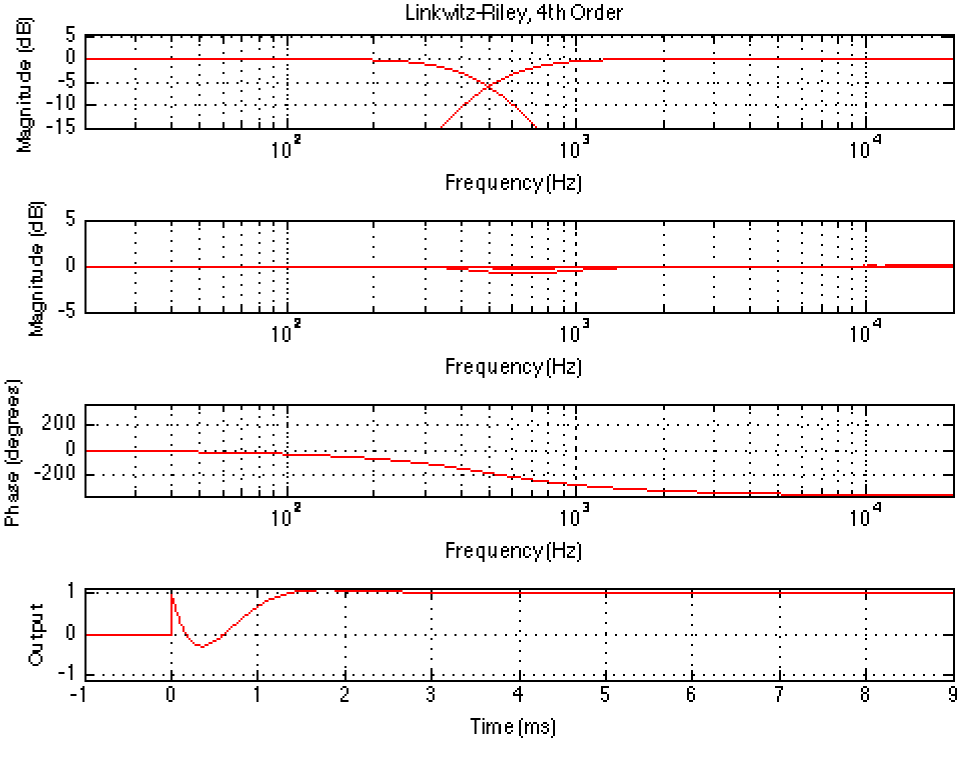


Figure 13. Linkwitz-Riley 4th Order frequency response curve

frequency response graph showing the smooth transitions of a 4th-order Linkwitz-Riley crossover

As you can see, the frequency response of the crossover is very smooth. There are no audible artifacts, such as "notches" or "bumps". This ensures that the sound produced by the loudspeakers is accurate and natural.

FUTURE SCOPE

A two-way active crossover using op-amps is a great project choice, as it allows for precise control over the frequency response of an audio system. It divides the audio signal into two separate frequency ranges (usually low and high frequencies) and sends them to the appropriate speakers or amplifier channels.

Here are some potential future scopes or enhancements for your project:

Additional crossover points: You can expand your project to include more than two crossover points. This would allow you to create a multi-way active crossover system, dividing the audio signal into three or more frequency ranges. Each range can be routed to dedicated speakers or amplifier channels for improved audio quality and accuracy.

Digital signal processing (DSP): Consider integrating digital signal processing capabilities into your active crossover system. DSP chips or microcontrollers can provide advanced filtering algorithms, adjustable equalization, time alignment, and other audio processing features. This would enhance the flexibility and customization options of your crossover system.

Wireless connectivity: Add wireless connectivity options to your crossover system, allowing it to receive audio signals wirelessly. You can incorporate Bluetooth, Wi-Fi, or other wireless technologies to stream audio from various sources such as smartphones, tablets, or computers. This would provide more convenience and versatility in setting up and controlling your audio system.

Remote control and automation: Implement remote control functionality using infrared (IR), radio frequency (RF), or other wireless communication methods. This would allow you to adjust crossover frequency settings, equalization, volume, and other parameters without physically accessing the hardware. Automation features like pre-set configurations, audio scene switching, or integration with smart home systems can also be considered.

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