Active Low Pass Filter

Pavani S1, Talamarla Saicharan2, Mr. Bharath Kumara3

1 Student, Electronics and Communication Engineering, MSRUA, Karnataka, India
2 Student, Electronics and Communication Engineering, MSRUA, Karnataka, India
3 Associate Professor, Electronics and Communication Engineering, MSRUA, Karnataka, India

ABSTRACT

In this paper we are going to discuss about Filters, categories of filters, Active low pass filter, active low pass filter circuit, first order and second order active low pass filter, voltage gain of active low pass filter, frequency response and applications of active low pass filters.

We need filters for the purpose of desired communication in day to day life. In this paper we are going to know the importance of filters and the use of Active low pass filter and its working.

Keywords: - Cut-off frequency, Attenuation, Gain, Frequency response.

1. INTRODUCTION

Why do we need filters?

There is a wide range of frequencies present in our surroundings, but we need different frequencies for different applications. Like audio frequency ranges from 20 Hz to 20 kHz, video transmission needs a bandwidth of 4.2 MHz, a TV signal needs a bandwidth of 6MHz. For all these, we need to select the different frequencies where the specific signal’s transmission is possible. A circuit which does this selection of frequency is called as a Filter or a Filter circuit. The basic need for the filter circuits is in high stereo systems for best sound quality and power efficiency, where a particular range of the audio frequency is to be amplified or suppressed.

1.1 Types of Filters:

Filters are of two types:

1) Passive Filters: Passive filters consists of passive elements such as resistors, inductors and capacitors so there is no signal gain, hence the output level is always less than the input.

2) Active filters: Active filters consists of active elements, which are amplifying elements like op-amps, transistors, FET’s so there is signal gain, hence the output level is greater than the input.

The gain is never greater than unity in the passive filters and that the load impedance affects the filters characteristics causing Attenuation. One way of regaining the signal is by amplifying using the Active filters. Active filters extract power from an external power source amplify the output signal.

An active filter uses an operational amplifier, as an Op-amp has a high input impedance, a low output impedance and voltage gain can be determined by the circuit.

1.2 Categories based on bandwidth allowance:

Basically, there are four categories of filters:

1) Low pass filter.
2) High pass filter.
3) Bandpass filter.
4) Band-stop filter.
In this paper let us discuss about Low pass filter.

2. Active Low Pass filter:

Low pass filters are the filters which allows all frequencies up to upper cut-off frequency $f_h$ and attenuates signals above this frequency. By combining a basic RC Low pass filter circuit with an operational amplifier, we can make an Active Low pass filter circuit, which also amplifies.

![Figure 1: Basic Active low pass Filter.](image)

Filter amplification is also used to shape the frequency response of the filter circuit by generating an exact output response, making the output bandwidth of the filter narrow or wide.

2.1 Frequency response of ideal low pass filter:
The frequency response is the frequency range that the amplifier is designed to amplify. Ideally, the frequency response curve drops at the cut-off frequency, as shown in figure 2. Practically the signal drops from transition region to the stop band region. Hence, this filter is also called as treble cut filter or high-cut filter.

- Transition region is the area at which falloff occurs.
- Stop band region is the area at which the input signal attenuation happens.

![Figure.2: Frequency response of an ideal active low pass filter](image)
2.2 Active low pass filter circuit:
In a passive circuit the attenuation of the signal is lesser than amplitude of the input signal. In order to overcome this, an active filter is used. A Passive filter is connected to the inverting or non-inverting op-amp to get an active low pass filter. First order active filter is done by a single op-amp with RC circuit.

![Active low pass filter circuit diagram](image)

**Figure 3:** A simple RC Passive Filter connected to the non-inverting terminal of an operational amplifier.

This RC circuit gives a low frequency path as the input to the amplifier. The amplifier provides unity gain output by acting as a buffer circuit, with more input impedance value. The input impedance is limited by the series impedance $R + \frac{1}{j\omega C}$, though the input impedance of the op-amp is high under the cut-off frequency.

The output impedance of the op-amp is always low, providing high stability to filter. The main disadvantage of this configuration is that the voltage gain is unity.

Voltage gain of a first order Active low pass filter:

A unity gain is not enough for the purpose of amplification. So we add a buffer to the output side to get high voltage gain, as shown in the figure 4.

![First order Active low pass filter diagram](image)

**Figure 4:** First order Active low pass filter to get high voltage gain.
The input signals at low frequencies will pass through the amplifying circuit, whereas the high input frequency signals are passed through the capacitor C1. The output signal amplitude is increased by the pass band gain of this filter. The magnitude of the voltage gain is obtained by its feedback resistor $R_2$ divided by its corresponding input resistor $R_3$ for a non-inverting amplifier circuit.

This is given as follows

$$\text{Magnitude of the voltage gain} = 1 + \frac{R_2}{R_3}$$

But we know that the gain can be obtained by the frequency components also,

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}} = A_{max} \sqrt{1 + \left(\frac{f}{f_c}\right)^2}$$

Where,

- $V_{out}$ = Output voltage
- $V_{in}$ = Input Voltage
- $A_{max}$ = Gain of the pass band = $1 + \frac{R_2}{R_3}$
- $f$ = operational frequency
- $f_c$ = Cut-off frequency = $\frac{1}{2\pi RC}$ Hz

As the frequency increases, for every 10 time increment of frequency there is a decrease in gain by 20 dB.

At low frequencies when $f > f_c$, then

$$\frac{V_{out}}{V_{in}} = A_{max}$$

When $f = f_c$, then

$$\frac{V_{out}}{V_{in}} = \frac{A_{max}}{\sqrt{2}} = 0.707A_{max}$$

When $f < f_c$, then

$$\frac{V_{out}}{V_{in}} < A_{max}$$
By the above three equations we can say that at low frequencies the gain of the circuit is equal to maximum gain and the circuit gain is less than maximum gain $A_{\text{max}}$ at high frequencies. When the actual frequency is equal and cut-off frequency are same, then the gain is equal to the 70.7% of the $A_{\text{max}}$.

The magnitude of the Voltage Gain in decibels(dB) is given as:

$$A_{\text{max}} = 20 \log_{10} \frac{V_{\text{out}}}{V_{\text{in}}}$$

The gain at -3 dB frequency is given as:

$$-3 \text{ dB } A_{\text{max}} = 20 \log_{10} (0.707 \frac{V_{\text{out}}}{V_{\text{in}}})$$

3. Second-order Low Pass Active Filter

A second-order low pass filter can be done by adding an extra RC network in the input path to the first-order low-pass active filter. The frequency response of the second-order low pass filter is similar to the first-order, but the stop band roll-off will be double the first-order filters at 40dB per decade.

![Second order active low pass filter circuit.](image)

Figure 5: Second order active low pass filter circuit.

$$A_{\text{max}} = 1 + \frac{R2}{R1}$$

$$f_c = \frac{1}{2\pi \sqrt{R3R4C1C2}}$$
Second-order active filter is important, as higher-order filters can be made using them. Filters with any order value of either odd or even can be constructed by cascading together first and second-order filters.

3.1 General frequency response curve for the practical filter:

By the above analysis the frequency response curve for the practical filter can be explained as in the figure 6:

![Figure 6: The frequency response of an Active low pass filter](image)

The corner frequency of the filter would be affected if the external impedance connected to the input of the filter circuit changes. Placing the capacitor in parallel with the feedback resistor will avoid the changes made by the external factors.

4. Applications:

Applications of Active low pass filter:

- In electronics active low pass filters are widely used in many applications.
- In audio speakers they are used as hiss filters to reduce the high frequency hiss produced in the system and for subwoofers they are also used as inputs.
- They can be used as anti-aliasing filters to control signals in analog to digital conversion.
- They can be used to block harmonic emissions in radio transmitters.
- These filters are used to filter the high frequency signals, which cause echoes at higher frequencies while transmitting.
- Used in telephone systems to convert the frequencies of audio in the speaker to a band-limited voice band signal.
- LPFs are used to filter noise from a circuit
- Low pass filter is used for enhancing the image, smoothing sets and blurring of images can be done by digital filters
- Used as an integrator in an RC circuit
- Low pass filter is used in analyzing the signals coming from the human body which have less frequency. So that these signals can pass through LPF and remove unwanted sound.
5. Conclusions:
We have investigated the need of filters in daily life. And the importance of low pass filters for the purpose of communication is studied. The types of filters and its categories are useful for different applications in each domain of communication. The working, the circuit of active low pass filter is analyzed for the purpose of low frequency allowance in many applications with sensitive signals. The voltage gain under the case of unity feedback and a valued feedback is obtained.

6. REFERENCES: