**Design of analog Filter circuit based on Multisim**

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**Abstract.** With the rapid development of electronic technology, the filter circuit has been widely used in various occasions. Therefore, based on the study of various analog filter circuit principles, this paper uses the Multisim simulation platform to design the corresponding low-pass and band-pass filters. In order to verify the performance of the filter circuit, the normal signal, noise signal and filter output signal are respectively observed by oscilloscope after noise is introduced, and then the performance is analyzed according to the waveform and parameters. The experimental results show that all the designed filters can achieve good filtering effect.

**Keywords:** Low-pass filter, High pass filter, Bandpass filter, Band-stop filter, The simulation analysis.

1. **Introduction**
With the development of electronic technology, analog filter has been widely used in all kinds of automatic measurement and control system and telecommunication equipment, and has been widely used in various fields of electronic technology [1]. In many applications, such as signal processing, data transmission and interference suppression, filters can be seen to play a role, and the merits and demerits of the filters in the circuit directly affect the merits and demerits of the products.

Common analog filters are divided into passive and active types [2]. Passive filters, also known as passive networks, generally consist only of resistors, capacitors, or inductors. Active filter is also known as active network, using operational amplifier as voltage source or current source, plus RC network formed [3]. Apf is more widely used than passive filter because of its light weight, small size and convenient tuning.

2. **Principle and design of common filter circuit**

2.1. **Low pass filter circuit**
A low-pass filter, as its name suggests, allows low-frequency signals to pass through and blocks or inhibits high-frequency signals. Common low-pass filters generally have no source and active low-pass filters. The classical passive low-pass filter is shown in Figure 1.
Its transfer function is

\[ H(\omega) = \frac{V_o}{V_i} = \frac{1}{j\omega C} - \frac{1}{1 + jR \omega C} \]

(1)

Its amplitude-frequency characteristics are shown in Figure 2, and its cut-off frequency is:

\[ f_c = \frac{1}{2\pi RC} \]

With amplitude-frequency characteristics, it can be seen that the gain of the circuit changes slowly with frequency. The passive RC low-pass filter circuit is usually simple, but the attenuation rate in the stop-band area is slow. And the load of the filter circuit will change the filter characteristics, usually can only be used in some less demanding places.

Active power filter (APF) is generally used for high signal processing requirements[4]. APF circuit is generally composed of passive filter circuit and outgoing amplifier. As shown in FIG. 3, the first-order active low-pass filter consists of a first-stage RC low-pass filter circuit and a voltage follower.
2.2. High pass filter circuit
In contrast to the low-pass filter, the high-pass filter passes through the high-frequency signal almost without attenuation, and the low-frequency signal is suppressed or attenuated. The characteristics of the ideal high-pass filter are shown in Figure 4.

![Fig 4. Ideal high-pass filtering Characteristics](image)

The high-pass filter circuit is similar to the low-pass filter circuit, which can be simply composed by the RC circuit, as shown in Figure 5, and its transfer function is

\[
H(j\omega) = \frac{U_o}{U_i} = \frac{R}{R + 1/j\omega C} = \frac{1}{1 + 1/j\omega RC} = \frac{1}{1 - j\frac{\omega_0}{\omega} + \frac{1}{R}}
\]

(2)

Like the low-pass filter circuit, the first-order RC high-pass filter circuit has a simple structure, but the signal has energy loss and obvious load effect, and it is easy to cause electromagnetic induction, and the load will affect the filtering characteristics. Therefore, active high pass filter is generally required for high occasions, as shown in FIG. 6.

![Fig 5. First-order RC high-pass filtering circuit](image)

![Fig 6. First-order ACTIVE High pass filter](image)
2.3. Band-pass filter circuit
The band-pass filter only allows the signal of a certain frequency band to pass, and the signal beyond the two ends is suppressed or attenuated\[5\]. Its circuit structure design can be composed of a low-pass filter circuit and a high-pass filter circuit, mainly design the cutoff frequency of the low-pass filter circuit and high-pass filter circuit respectively, then the band-pass filter can be realized. The details are shown in Fig.7.

\[H(j\omega) = \frac{U_2}{U_1} = \frac{j\omega RC}{1 - \omega^2 RC^2 + j3\omega RC}\] (3)

Practical band-pass filters are often active. Similar to active low-pass and high-pass, active band-pass filter is also composed of RC network and integrated operational amplifier, which will not be discussed in detail.

2.4. Principle of band-stop filter circuit
In contrast to a band-pass filter, a band-stop filter is designed to suppress or attenuate signals at a certain frequency band, while signals at other frequencies can pass smoothly. Its design method is very similar to the circuit of band-pass filter, and its structure is also composed of low-pass filter and high-pass filter, which will not be discussed in detail.

3. Design and simulation of filter circuit
Due to space limitation, this paper only simulates the low-pass filter circuit and the band-pass filter circuit. A second-order low-pass filter circuit was built using Multisim software, as shown in FIG. 8.

V1 is 10kHz noise signal, V2 is 1kHz normal signal, Channel A is connected to V2 is 1kHz normal signal, channel B is connected to noise signal, channel C is connected to filter output signal, as shown in Fig. 9.
Fig 9. Filtering effect diagram of low-pass filter

As can be seen from the oscilloscope, the X-axis scan is 500us/Div, the Y-axis amplitude of Channel A is 200mv/Div, and the partial value is 2. The Y-axis amplitude of channel B is 20mv/Div, and the partial value is 0; The Y-axis amplitude of channel C is 500mv/Div, and the partial value is -2. The upper green line above is a signal waveform of 1kHz on the A channel. the middle blue line is the signal waveform of 1kHz and 10kHz of the B channel, that is, the input signal of the low-pass filter; The lower purple line is the output signal waveform of the low-pass filter of the only channel. Compared C signal and A signal, except for the slight difference in amplitude and phase, their frequencies are exactly the same, that is, the low-pass filter filters out the high-frequency signals from B signal, or only lets the low-frequency signals from B signal pass through, so as to achieve the filtering function, as shown in Fig 10.

Fig 10. Active band-pass filter circuit

V1 is 10kHz high frequency noise signal, V2 is 1kHz normal signal, V3 is 100Hz low frequency noise signal. Channel A is connected to V3 is 100Hz normal signal, channel B is the sum of normal signal and low frequency noise signal, channel C is connected to the signal mixed with V1, V2, V3, and channel D is the output signal of filter circuit, as shown in Fig 11.
As can be seen from the oscilloscope, the X-axis scan is $2\mu s/Div$, the Y-axis amplitude of Channel A is $50mV/Div$, and the partial value is 2. The Y-axis amplitude of Channel B is $50mV/Div$, and the partial value is 0.8; The Y-axis amplitude of Channel C is $200mV/Div$, with a bias value of -0.8; the Y-axis amplitude of channel D is $200mV/Div$ with a bias value of -2. The first green line is the $100\,Hz$ signal waveform of channel A, the second blue line is the $100\,Hz$ signal waveform superposition of channel B with $1\,KHz$, the third yellow line is the signal waveform superposition of $100\,Hz$, $1\,KHz$ and $10\,KHz$ signal channel C, and the fourth purple line is the signal waveform output by the band-pass filter of channel D. It can be seen that this is formed by filtering out the low-frequency and high-frequency components from the C signal and selecting only the $1\,KHz$ signal, thus realizing the filtering function.

4. Summarizes
In this paper, Multisim software is used as the platform to study a variety of filtering circuits. Firstly, the basic principles of basic second-order low-pass filter, second-order high-pass filter, second-order band-pass filter and second-order band-stop filter are analyzed. Then the software was used for circuit simulation: the amplitude-frequency characteristic curve and phase-frequency characteristic curve of these filters were clearly observed on the simulated oscilloscope, and the output signals before and after filtering were observed and compared, and finally a conclusion was reached.

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