سجل التجارب للعام الدراسي 2023-2024

Experiment No.2: Active Filter

What is an Active Filter: An active filter is a type of analog electronic filter that uses active components, typically amplifiers, to improve performance, cost, and predictability. Unlike passive filters, active filters can have complex poles and zeros without bulky inductors. They are designed to pass specific frequency bands while attenuating others, with the ability to adjust parameters like the quality factor and tuned frequency through variable resistors.

Active filters are used in various applications where precise filter characteristics are needed, such as in audio processing, signal conditioning, and communication systems.

There are four types of filters; low-pass, high-pass, band-pass, and band-elimination (also referred to as band-reject or notch) filters.

1/ Active Low Pass Filter (LPF)

An active low-pass filter is an electronic circuit that permits only low-frequency components to pass through while attenuating higher-frequency components.

1. **Principle of Operation**:
    - An active low-pass filter combines a **basic RC low-pass filter** circuit with an **operational amplifier (op-amp)**.
    - The op-amp provides **amplification** and **gain control** to the filter.

- The input to the op-amp is a **high-impedance signal**, and the output is a **low-impedance signal**.
- The frequency response of the active low-pass filter is similar to that of a passive low-pass filter.
- The main difference is that the active filter uses an op-amp for amplification.

2. **Circuit Diagram**:
   - The simplest form of an active low-pass filter involves connecting an **inverting or non-inverting amplifier** (similar to those discussed in the op-amp tutorial) to the basic RC low-pass filter.
   - The RC filter provides the frequency-selective behavior, and the op-amp amplifies the filtered signal.

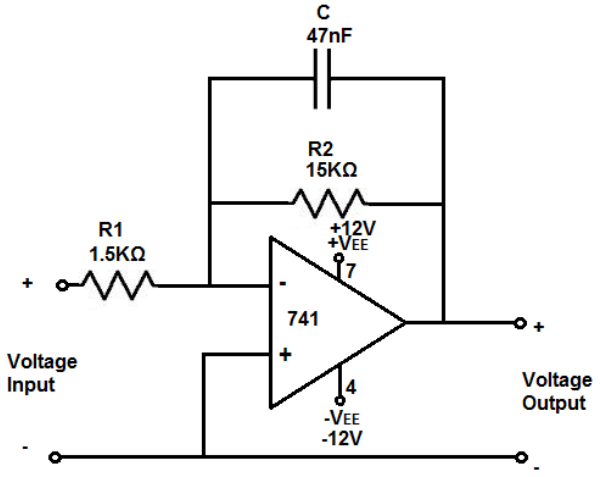

Fig. 1 The circuit of active low pass filter.

3. **Advantages of Active Low-Pass Filters**:
   - **Amplification**: Unlike passive filters, active filters can **boost the output signal** using the op-amp.

- **Selective Response**: Active filters allow more precise control over the filter's response, making it narrower or wider.
- **Accuracy**: Active filters exhibit good performance characteristics, steep roll-off, and low noise when designed properly.

4. **Applications**:
   - **Audio Systems**: Active low-pass filters are commonly used in audio processing to remove high-frequency noise.
   - **Signal Conditioning**: They help shape signals for further processing.
   - **Anti-Aliasing Filters**: In data acquisition systems, active low-pass filters prevent aliasing by attenuating high-frequency components before sampling.

frequency-response plot for the four types of filters. A low-pass filter is a circuit that has a constant output voltage from dc up to a cutoff frequency fc. As the frequency increases above fc, the output voltage is attenuated (decreases). The figure below is a plot of the magnitude of the output voltage of a low-pass filter versus frequency. The range of frequencies that are transmitted is known as the pass band. The range of frequencies that are attenuated is known as the stop band. The cutoff frequency fc is also called the 0.707 frequency, the 3-dB frequency, the corner frequency, or the break frequency.

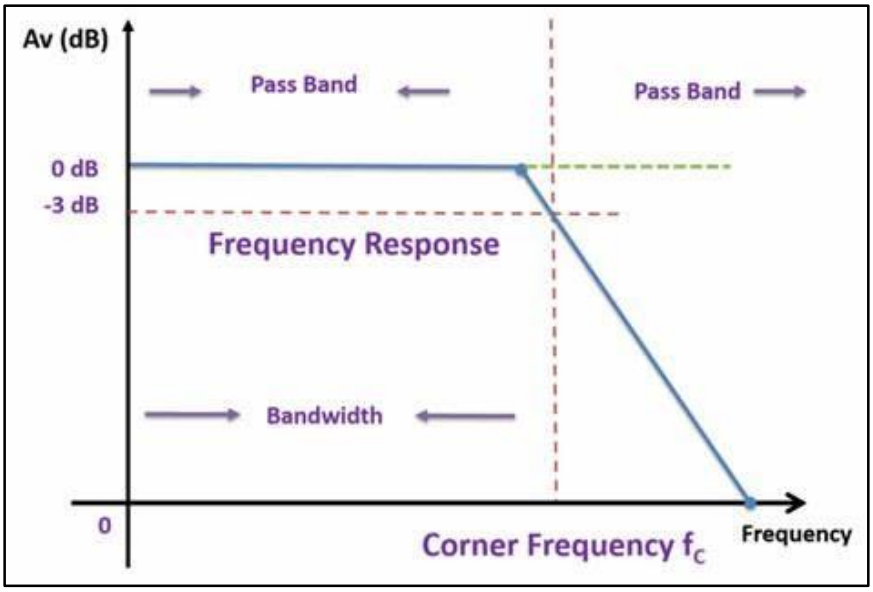

Fig. 2 Frequency responses of active low-pass filter.

2/ Active High Pass Filter (HPF)

An active high-pass filter is an electronic circuit that allows high-frequency components of a signal to pass through while attenuating lower-frequency components.

1. **Principle of Operation**:
    - An active high-pass filter combines a **basic RC high-pass filter** circuit with an **operational amplifier (op-amp)**.
    - The op-amp provides **amplification** and **gain control** to the filter.
    - Similar to the active low-pass filter, the active high-pass filter uses an op-amp for amplification.
    - The frequency response of the active high-pass filter is similar to that of a passive high-pass filter.

2. **Circuit Diagram**:
    - The simplest form of an active high-pass filter involves connecting an **inverting or non-inverting amplifier** (similar to those discussed in the op-amp tutorial) to the basic RC high-pass filter.
    - The RC filter provides the frequency-selective behavior, and the op-amp amplifies the filtered signal.

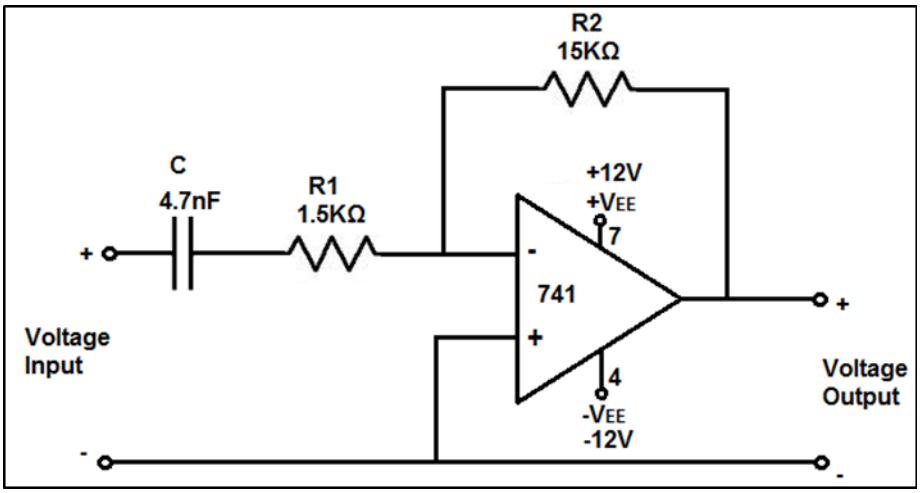

Fig. 3 The circuit of active high pass filter.

3. **Advantages:**

A. **Frequency Selectivity**:

- Active high pass filters allow you to selectively pass high-frequency components while attenuating low-frequency signals.
- By adjusting the filter's cutoff frequency, you can tailor it to specific applications, such as audio, communication, or instrumentation.

B. **Amplification**:
   - Unlike passive filters, active high pass filters incorporate an operational amplifier (op-amp) that provides **amplification**.
   - The op-amp compensates for the signal loss across the filter, ensuring that the output signal has sufficient strength.

C. **Low Output Impedance**:
   - Active filters have a **low output impedance**, which means they can drive loads (such as other circuits or devices) effectively.
   - This is especially useful when connecting the filter to subsequent stages in a signal chain.

D. **Adjustable Gain**:
   - Op-amp-based active filters allow you to adjust the gain (amplification) of the filter.
   - You can control the gain by selecting appropriate resistor values in the feedback network.

E. **Improved Signal-to-Noise Ratio (SNR)**:
   - Active filters can enhance the SNR by amplifying the desired high-frequency signals while minimizing noise.
   - The op-amp's inherent noise contribution is generally negligible compared to the benefits gained.

F. **Stability and Predictability**:
   - Active filters are more stable and predictable than passive filters.
   - Their performance is less affected by variations in component tolerances and temperature changes.

G. **Higher Order Filtering**:

- Active high-pass filters can achieve higher-order filtering (e.g., second-order, third-order, etc.) by cascading multiple stages.
- This allows for sharper roll-off characteristics and better attenuation of unwanted frequencies.

H. **Design Flexibility**:

- Active filters offer greater flexibility in design.
- You can easily modify the filter parameters (such as cutoff frequency, gain, and Q factor) by adjusting resistor and capacitor values.

4. Application:

Active high-pass filters find practical applications in various fields due to their ability to selectively allow high-frequency components while attenuating low-frequency signals. Here are some examples:

A. **Audio Systems**:

- **Tweeter Protection**: In stereo systems, a capacitor connected in series with the tweeter (treble) speaker serves as a high-pass filter. It imposes a high impedance to low-frequency bass signals, preventing wasted power on a speaker inefficient for reproducing such sounds.

B. **Telecommunications**:

- **Signal Conditioning**: Active high pass filters are used to condition signals in communication systems. They remove unwanted low-frequency noise or interference, allowing only relevant high-frequency components to pass.
- **Antenna Design**: High pass filters help eliminate unwanted low-frequency noise from antenna signals, ensuring cleaner reception.

C. **Instrumentation and Measurement**:

- **Sensor Signal Processing**: Active high pass filters enhance the accuracy of sensor measurements by eliminating low-frequency noise. For example, in temperature sensors, they remove slow drifts caused by environmental changes.
- **Frequency Response Analysis**: Engineers use active high pass filters to analyze frequency response characteristics of electronic circuits and devices.

D. **Biomedical Applications**:

- **Electrocardiography (ECG)**: Active high pass filters remove baseline drift and low-frequency noise from ECG signals, allowing clear detection of heart-related events.
- **Electromyography (EMG)**: EMG signals contain both low and high-frequency components. Active high pass filters help isolate muscle activity by removing baseline noise.

E. **Signal Processing and Music Production**:

- **Equalization**: Active high pass filters are part of equalizer circuits used in music production. They boost or attenuate specific frequency bands to achieve desired tonal balance.
- **Crossover Networks**: In audio systems, active high pass filters separate signals for different frequency ranges (e.g., bass, midrange, and treble) before sending them to dedicated speakers.

F. **RF and Microwave Applications**:

- **RF Amplifiers**: Active high-pass filters are used in RF amplifiers to prevent low-frequency interference from affecting the amplifier's performance.

- **Antenna Tuning**: They help tune antennas by allowing only high-frequency signals to propagate efficiently.

G. **Vibration Analysis and Structural Health Monitoring**:

- **Accelerometers**: Active high-pass filters process accelerometer data to focus on high-frequency vibrations associated with structural defects or machinery faults.

High-pass filters attenuate the output voltage for all frequencies below the cutoff frequency fc. Above fc the magnitude of the output voltage is constant. The figure below is the plot for ideal and practical high-pass filters.

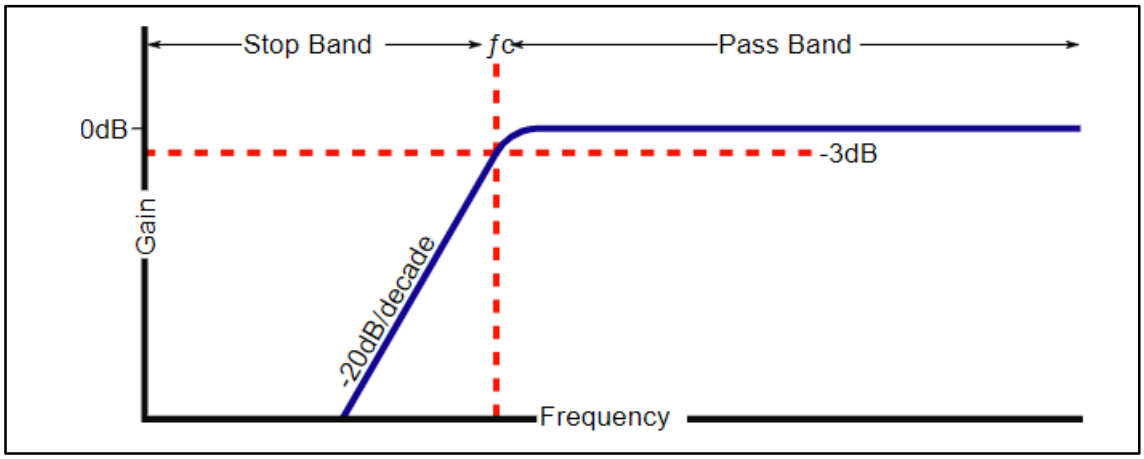

Fig. 4 Frequency responses of active high-pass filter.

Note// **Cutoff frequency** of an **active filter**, such as an **active low-pass filter**, and **an active high-pass filter** is a crucial parameter that determines the transition from the passband to the stopband. The cutoff frequency (also known as the **-3 dB point**) is the frequency at which the filter's output power (or amplitude) drops to half of its maximum value.

In other words, it's the frequency where the gain of the filter decreases by 3 dB (decibels) from its maximum value in the passband.

Fig. 5 Semi Log graph paper.