CAD Lab Report

— Filters and RC-CR circuit

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- Filter is a kind of device constructed by capacitors, resisters and inducers. In electronic engineering, they are used to attenuate current at some frequencies in the circuit, in order to get some signals at specialized frequency. (LPF: Let frequency below its cut-off frequency pass through, but other frequencies above its cut-off frequency will be attenuated; HPF: Let frequency above its cut-off frequency pass through, but other frequencies below its cut-off frequency will be attenuated).
- An example of a passive low pass filter is as Figure 4. The gain and phase responses for it is followed. In this circuit, we choose $R = 4.9k\Omega$ and $C = 47nF$.

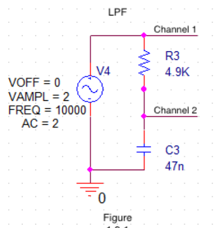
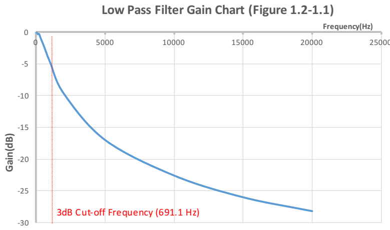
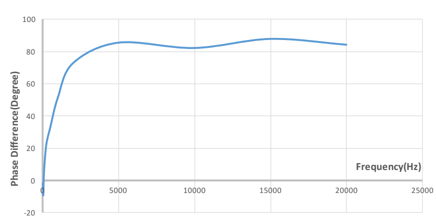


Figure 1.2-1



Low Pass Filter Gain Chart (Figure 1.2-1.1)



Low Pass Filter Phase Difference Chart (Figure 1.2-1.2)

An example of a passive high pass filter is as Figure 3. The gain and phase responses for it is followed. In this circuit, we choose $R = 4.9k\Omega$ and $C = 47nF$.

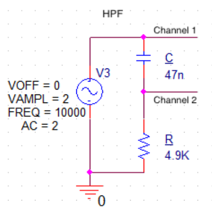
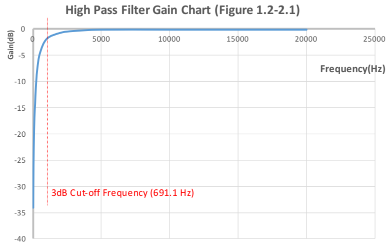
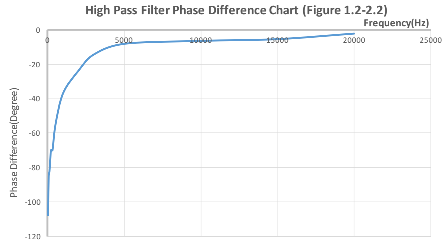


Figure 1.2-2



High Pass Filter Gain Chart (Figure 1.2-2.1)



High Pass Filter Phase Difference Chart (Figure 1.2-2.2)

- Generally speaking, our circuits were working. Because there is a significant change in the frequency interval between 500 Hz and 1k Hz in gained dB in our experiment, which is close to our theoretical cut-off frequency (691.1 Hz).

  (Because all of the data are got from the real experiment, the error may exist. For example, some strange points exist in the above chart. However, the trends showed by the charts are right.)
  We use the following formulas to calculate:

  Gained dB: $dB = 20log_{10}\frac{V_{out}}{V_{in}}$ Cut-off Frequency: $f_C = \frac{1}{2\pi RC}$

- A band-pass filter can be made by combining a CR circuit (high-pass filter) and a RC circuit (low-pass filter). Our band-pass filter is as Fig.2.1.1, which is followed by the gain plot (Fig.2.1.2) of it. We can connect a CR circuit and a RC circuit in series, in the whole circuit, the CR circuit can attenuate frequencies that are higher than its cut-off frequency f_H (3183.1 Hz). The RC circuit can attenuate frequencies that are lower than its cut-off frequency f_L (1446.9 Hz). Thus, if $f_H < f_L$, only a range of frequencies f ($f_H \leq f \leq f_L$) will be able to pass through the band-pass filter and other frequencies above and below that range will be attenuated.

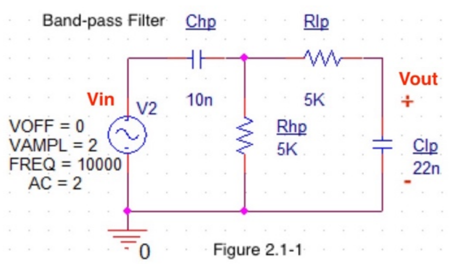
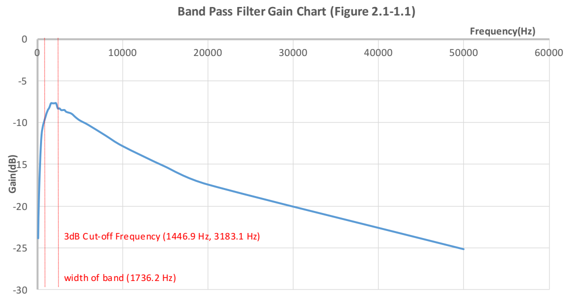


Figure 2.1-1



- For the active second order filter, the input impedance is much bigger than the passive second order filter. So, the voltage would not be influenced by the resistance of the input source much for the active second order filter compare with passive second order filter. For the second order filter, the 3dB cut off frequency (2511.9 Hz) would be smaller and the Gain-Frequency chart would be steeper and the filtering effect would be better.

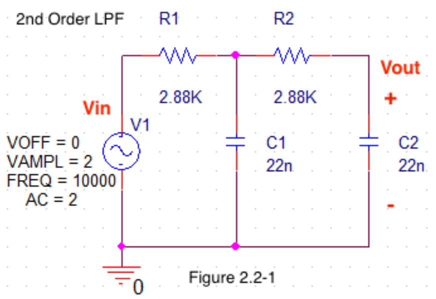
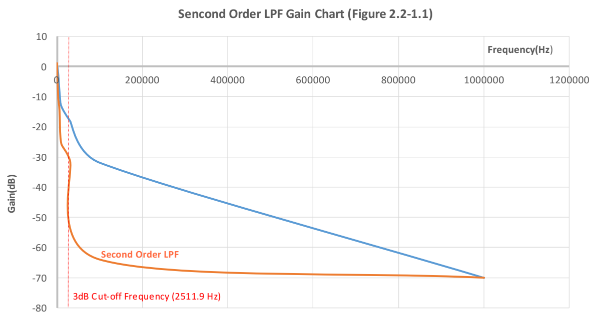


Figure 2.2-1



- ***Pros of second order filter:*** From the name, we simply can know that the second order filter filters the wave twice and gain a better filtered result compared with the first order filter, as getting a steeper Gain-Frequency chart (closer to the ideal one). (choose 1st and 2nd LPF as example)

$$f_{cut\,off-2nd\,order} = \frac{1}{5.3448RC\pi} \qquad f_{cut\,off-1st\,order} = \frac{1}{2RC\pi}$$

$$f_{cut\,off-2nd\,order} \leq f_{cut\,off-1st\,order}$$

  So second order filter's Gain-Frequency Chart would more close to the ideal one.

  Cons of second order filter: The second filter would cost more as it filters the wave for two times and it would also cause more phase difference to the output voltage.

- Our proposed designed for the audio amplifier circuit is as Figure 3.1-1, and its simulation results is as Figure 3.1-2. (The necessary comments are in the charts)

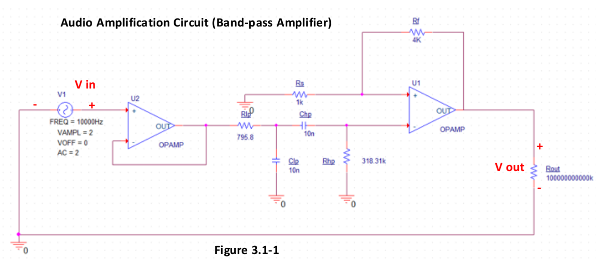
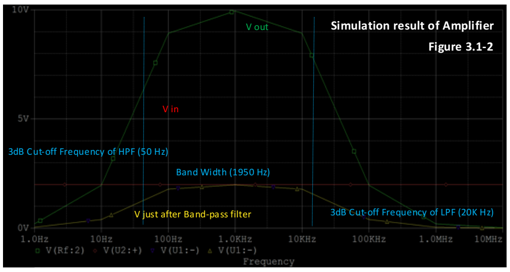


Figure 3.1-1



Simulation result of Amplifier

Figure 3.1-2

(The reason for Vout not be twice as the Vin is because the band-pass filter is not ideal and consume part of the voltage.)

- ***Reason to choose these components and calculation:*** First and foremost, we trying to derive the component of the circuit by adding a band-pass filter. So, U2 (OPAMP) is used to maximize the input resistance ($R_{input\ resistant} = \frac{V_{in}}{I_{in}} \approx \infty$), so the circuit would not be influenced by the inner resistance of the voltage source and the diverse of its value (to make the filter to be the active filter). Then, the resistor R_{lp} and capacitor C_{lp} form a low pass filter (LPF), the cut-off frequency (20K Hz) of which is the right cut-off point of the passing frequency band. The resistor R_{hp} and the capacitor C_{hp} form a high pass filter (HPF), the cut-off frequency (50 Hz) of which is the left cut-off point of the passing frequency band. By connecting the OPAMP, LPF and HPF in series, we can get an active band-pass filter. Because we want to remove every frequency component outside the range of human hearing (about 50~20000Hz), we should let the cut-off frequency of the LPF be around 20000Hz, and let the cut-off frequency of the HPF be around 50Hz. In order to make the calculation easier, we choose the capacitance of C_{lp} and C_{hp} to be 10nF, according to the formula $f_C = \frac{1}{2\pi RC} \Rightarrow R = \frac{1}{2\pi f_C C}$, we can get the acceptable value of these two resistor: $R_{lp} = 795.8\Omega$ & $R_{hp} = 318.3k\Omega$.
  We want to amplify the voltage of the signal by two times. According to the formula of amplifier $\frac{V_{out}}{V_{in}} = 1 + \frac{R_F}{R_S} \Rightarrow V_{out} = (1 + \frac{R_F}{R_S})V_{in}$, we can let the resistance of these two resistors R_F and R_S be $R_F = 4k\Omega, R_S = 1k\Omega$.
  The resistor R_{out} that has an extremely high resistance is used to simulate an open circuit between the V_{out} terminal and the ground in order to avoid the situation where $V_{out} = 0V$.
  We want to achieve: Amplify the input voltage by five (or n) times and filter the voltage input and just make output the voltage in a specific frequency band. That means $V_{out} = 5V_{just\ after\ the\ band-pass\ filter}\ (or\ n\ times)$ and frequency are in the range that: $f_{cut\ off\ HPF} < f < f_{cut\ off\ LPF}$.

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