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Circuit Theory and Devices

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Lab_2: LPF and BPF design in LTSpice

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Objective:

As we observed in the previous lab, the transmitter in the SONAR consists of a crystal oscillator that generates a 2MHz sinusoidal signal, and further using a frequency divider a 40KHz (fo) ultrasonic output signal is generated. A low pass filter is used to remove any higher order harmonics that may be generated in processing the signal on the transmitter side. Similarly on the receiver side, the received signal is amplified using a low noise amplifier and passed through a band pass filter to remove higher order harmonics and limit external interference. The filter on the transmitter side may be designed as an active filter to provide voltage amplification to the transmitted signal. The order of a filter is determined by the number of storage elements (capacitors and inductors). The first order LPF filters are series inductor or shunt capacitors.

Theoretical Calculations:

First order active low pass filter ⇒

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

here $f_c = 40kHz$

⇒ $R = 10k\Omega$

$C = 0.3nF$

Second order ative low pass filter ⇒

$$f_L = \frac{1}{2\pi\sqrt{R_3 C_1 R_4 C_2}}$$

$R_3 = R_4 = 10k\Omega$

$C_1 = C_2 = 0.3n$

$f_L = 20kHz$

First order Band Pass Filter ⇒

$$f_L = \frac{1}{2\pi R_L C_L} = 45kHz$$

$R_L = 10k\Omega$

$C_L = 0.355nF$

$$f_H = \frac{1}{2\pi R_H C_H} = 35kHz$$

$R_H = 10k\Omega$

$C_H = 0.455nF$

so, Bandwidth $= 45 - 35 = \boxed{10kHz}$

Second order Band Pass filter ⇒

$$f_L = \frac{1}{2\pi R_L C_L} = 45kHz$$

$$f_H = \frac{1}{2\pi\sqrt{R_{H1} C_{H1} R_{H2} C_{H2}}} = 35kHz$$

$R_L = 10k$

$C_L = 0.355n$

$R_{H1} = R_{H2} = 10k$

$C_{H1} = 0.455n$

$C_{H2} = 0.4n$

Edit : R1 = 10k, R2 = 40k, C1 = 100nF, C2 = 100nF

Observations:

First Order RC Low Pass Filter (LPF):

1. **Magnitude Response: As the frequency increases, the magnitude of the filter response decreases gradually. The roll-off of the filter's magnitude response is observed in the Bode plot.**
2. **Phase Response: The phase response of the first-order LPF changes as the frequency increases. At low frequencies, the phase shift increases as the frequency approaches the cutoff frequency.**

Second Order RC Low Pass Filter (LPF):

1. **Magnitude Response: The second-order LPF has a steeper roll-off compared to the first-order LPF.**
2. **Phase Response: Like the first-order LPF, the phase response of the second-order LPF changes as the frequency increases. The steeper roll-off is reflected in the phase response as well.**

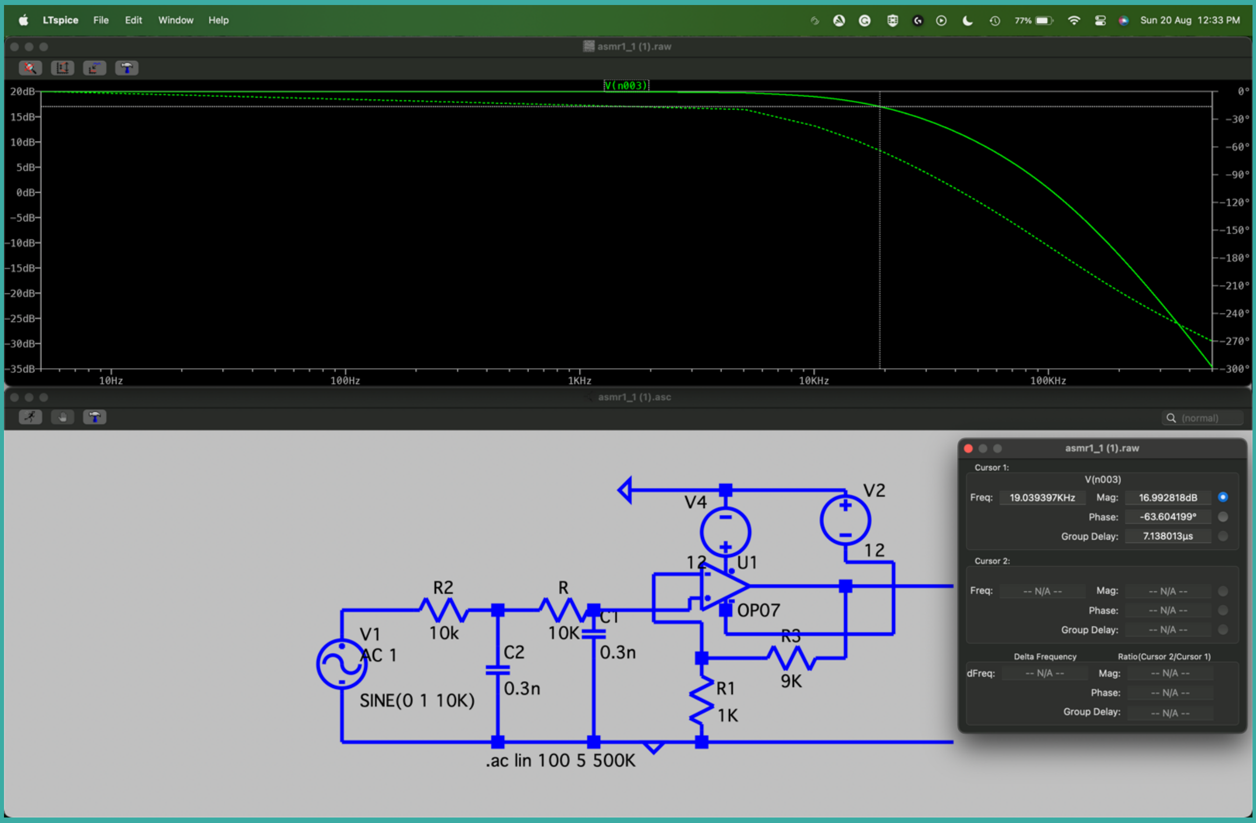
First Order RC Band Pass Filter (BPF):

1. **Magnitude Response: The magnitude response of the first-order BPF shows a peak around the center frequency. This peak corresponds to the passband of the filter, allowing frequencies within the specified bandwidth to pass through.**
2. **Phase Response: The phase response of the first-order BPF varies around the center frequency.**

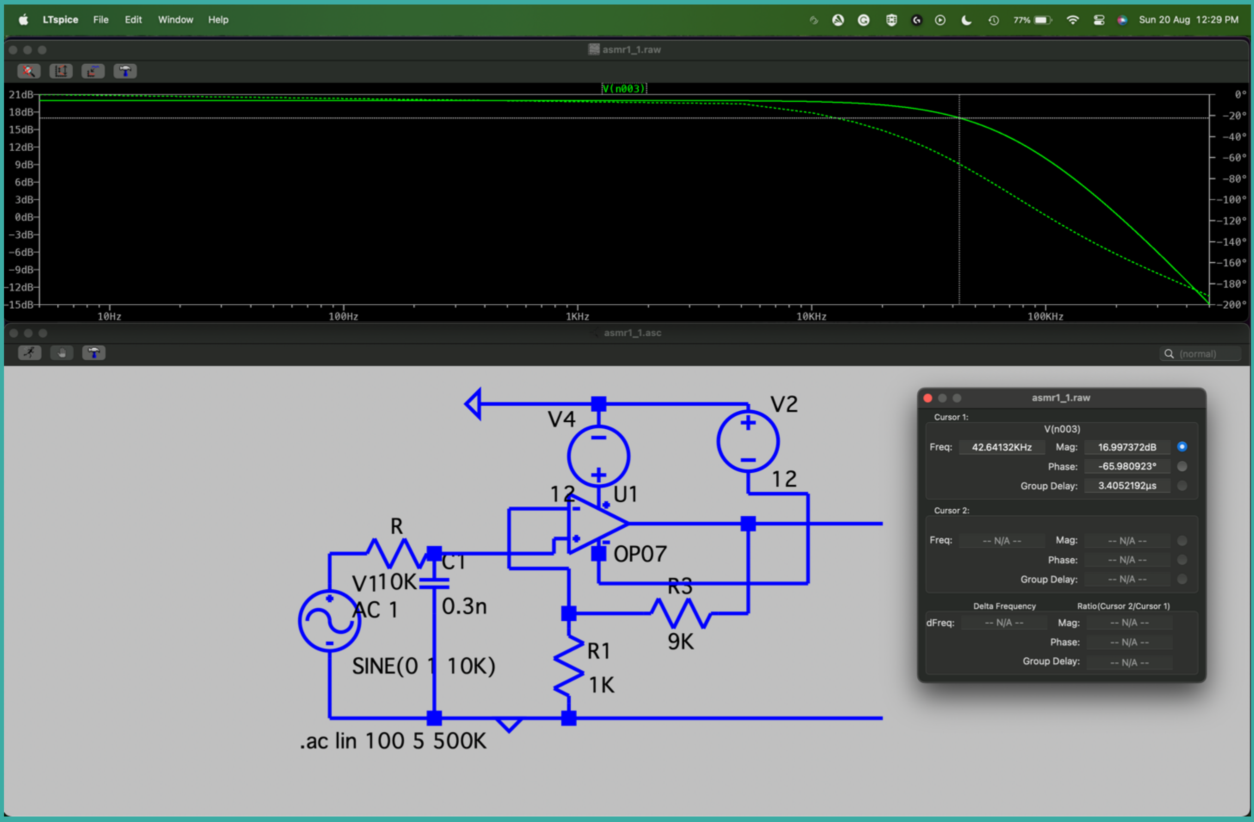
Second Order RC Band Pass Filter (BPF):

1. **Magnitude Response: The second-order BPF exhibits a narrower and more defined peak in the magnitude response compared to the first-order BPF.**
2. **Phase Response: The phase response of the second-order BPF also shows more defined changes around the center frequency.**

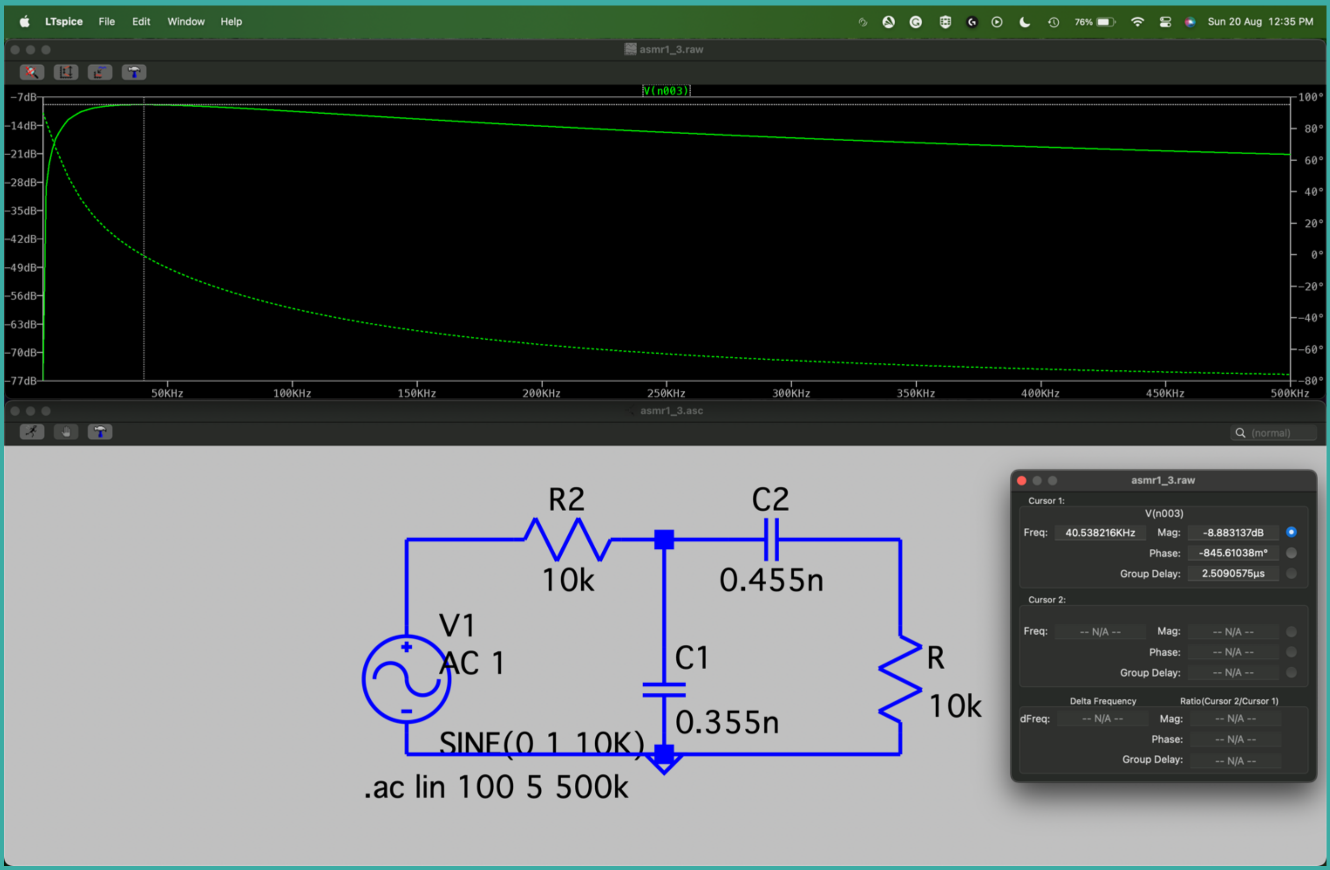
Plots:

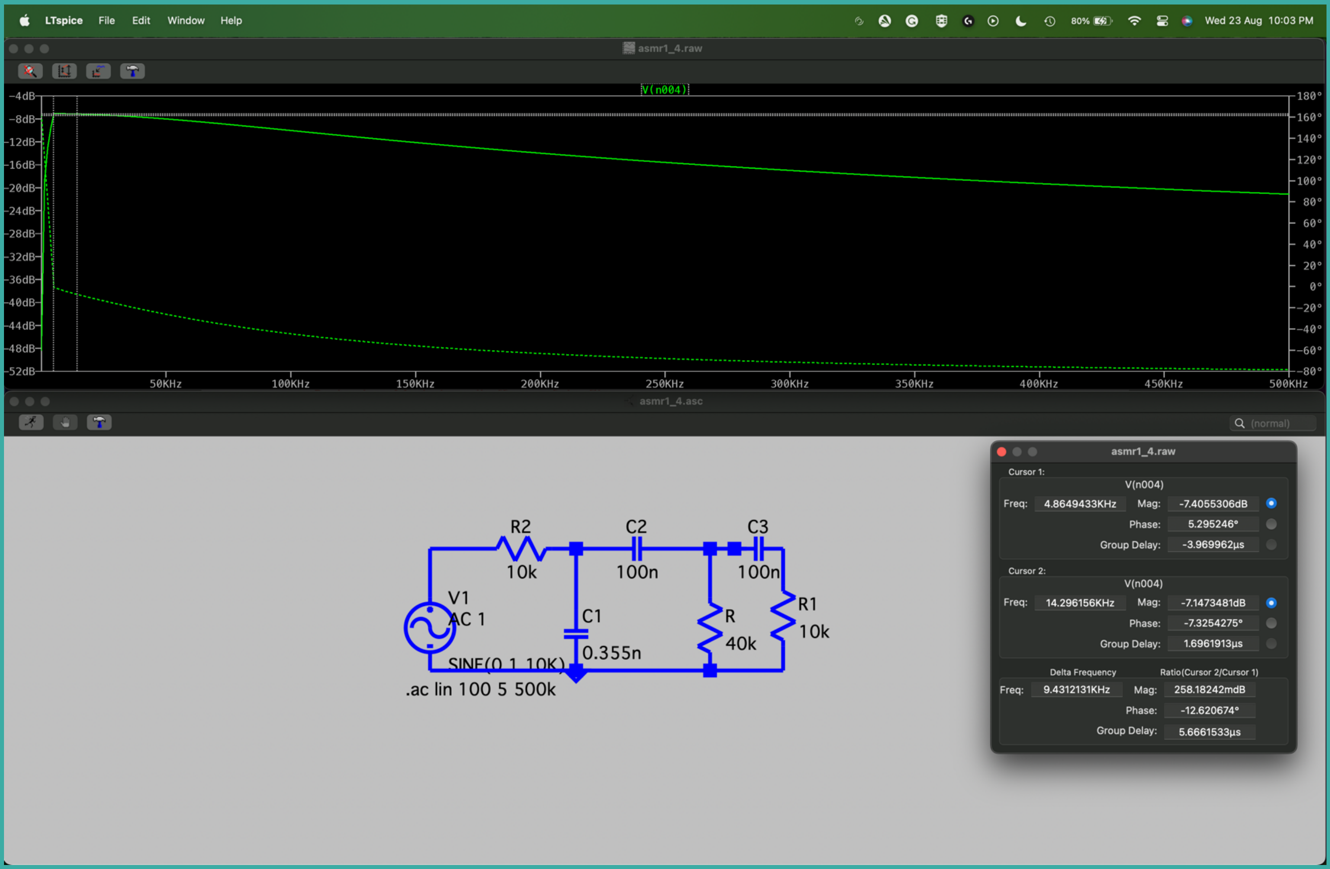


LTspice File Edit Window Help
Sun 20 Aug 12:33 PM
asmr1_1 (1).raw
V(n003)
10Hz
100Hz
1KHz
10KHz
100KHz
asmr1_1 (1).asc
V4
V2
12
U1
OP07
R2
10k
R
10K
C1
0.3n
C2
0.3n
V1
AC 1
SINE(0 1 10K)
R3
9K
R1
1K
.ac lin 100 5 500K
Cursor 1:
Freq: 19.039397KHz
Mag: 16.992818dB
Phase: -63.604199°
Group Delay: 7.138013µs
Cursor 2:
Delta Frequency
Ratio(Cursor 2/Cursor 1)



LTspice File Edit Window Help
Sun 20 Aug 12:29 PM
asmr1_1.raw
V(n003)
10Hz
100Hz
1KHz
10KHz
100KHz
asmr1_1.asc
V4
V2
12
U1
OP07
R
10K
C1
0.3n
V1
AC 1
SINE(0 1 10K)
R3
9K
R1
1K
.ac lin 100 5 500K
Cursor 1:
Freq: 42.64132KHz
Mag: 16.997372dB
Phase: -65.980923°
Group Delay: 3.4052192µs
Cursor 2:
Delta Frequency
Ratio(Cursor 2/Cursor 1)


LTspice File Edit Window Help
Sun 20 Aug 12:35 PM
asmr1_3.raw
V(n003)
-7dB
-14dB
-21dB
-28dB
-35dB
-42dB
-49dB
-56dB
-63dB
-70dB
-77dB
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
50KHz
100KHz
150KHz
200KHz
250KHz
300KHz
350KHz
400KHz
450KHz
500KHz
asmr1_3.asc
R2
10k
C2
0.455n
V1
AC 1
C1
0.355n
R
10k
SINE(0 1 10K)
.ac lin 100 5 500k
asmr1_3.raw
Cursor 1:
V(n003)
Freq: 40.538216KHz
Mag: -8.883137dB
Phase: -845.61038m°
Group Delay: 2.5090575µs
Cursor 2:
Freq: -- N/A --
Mag: -- N/A --
Phase: -- N/A --
Group Delay: -- N/A --
Delta Frequency
Ratio(Cursor 2/Cursor 1)
dFreq: -- N/A --
Mag: -- N/A --
Phase: -- N/A --
Group Delay: -- N/A --



Conclusions:

1. **Frequency Response: Filters exhibit different frequency responses based on their order and type. Low pass filters allow low frequencies to pass while attenuating high frequencies. Band pass filters allow a specific range of frequencies to pass.**

2. **Magnitude and Phase Responses: The Bode plots for both magnitude and phase responses provide insights into how filters behave across different frequency ranges. Magnitude response indicates the filter's gain behavior, while the phase response shows the phase shift introduced by the filter.**

3. **Higher Order Filters: Second-order filters exhibit steeper roll-offs and better selectivity compared to first-order filters. This increased selectivity is advantageous in applications where precise frequency control is required.**

4. **Cutoff Frequencies: The cutoff frequencies for the filters were determined by the values of the passive components (resistors and capacitors) used in their designs. Changing these values would result in different cutoff frequencies.**