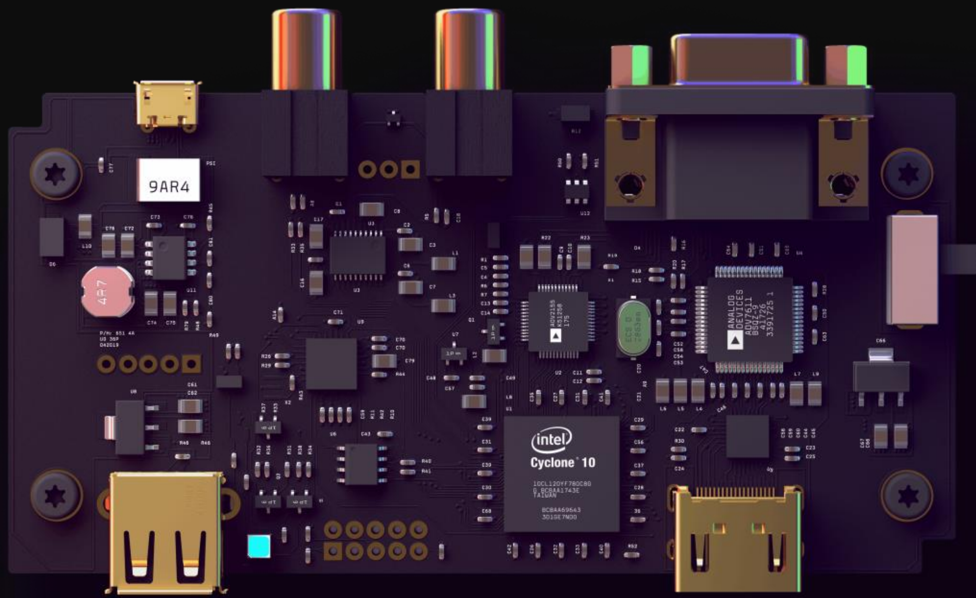
EC205

Analog Electronics Lab

Lab – 9



Utkarsh R Mahajan 201EC164

Sannan Ali 201EC159

Experiment 9: Second order Low-pass and High-pass filter

Aim: To design and study a µA741 based Sallen-Key Low-pass and High-pass filter

Circuit Diagram:

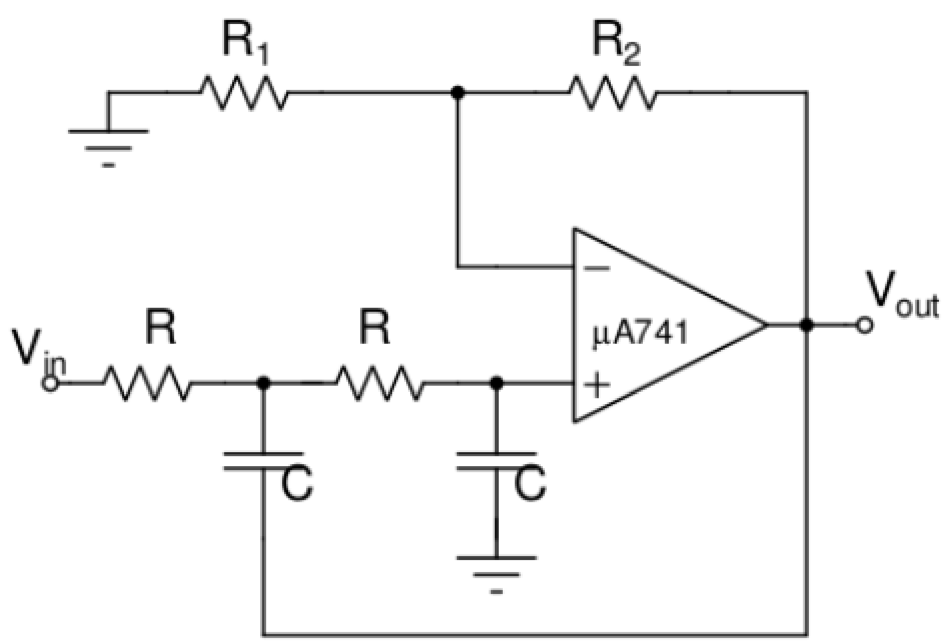


Figure 1: Sallen-key filter

1. Design the low-pass filter for three different Q values (0.5, 0.707 and 2) for a cut-off frequency = 1 kHz. Obtain the magnitude response and phase response. (For hardware lab: Note that the input signal should be such that the peak-to-peak value of the output Is at least 100 mV when the filter attenuation increases to 40 dB)

->

Transfer Function for low pass filter $H(S) = \frac{K}{(RCS)^2+(3-K)RCS+1}$

We know that for the following circuit, we get

$fc = \frac{1}{2\pi RC}$, and $Q = \frac{1}{3-K}$ where $K = 1+\frac{R2}{R1}$

considering R=1kΩ and using fc= 1 kHz.

$C = \frac{1}{2\pi R f c} = 0.1591\ \mu F$

From -40dB= 20log $\left(\frac{Vout}{Vin}\right)$, since Vout >= 100mV

Vin = 100Vout = 100 x 100×10^{-3} V = $10V_{p2p}$

For Q=0.5,

Let us consider R1 = 1kΩ

K=1, R2 has to be 0Ω.

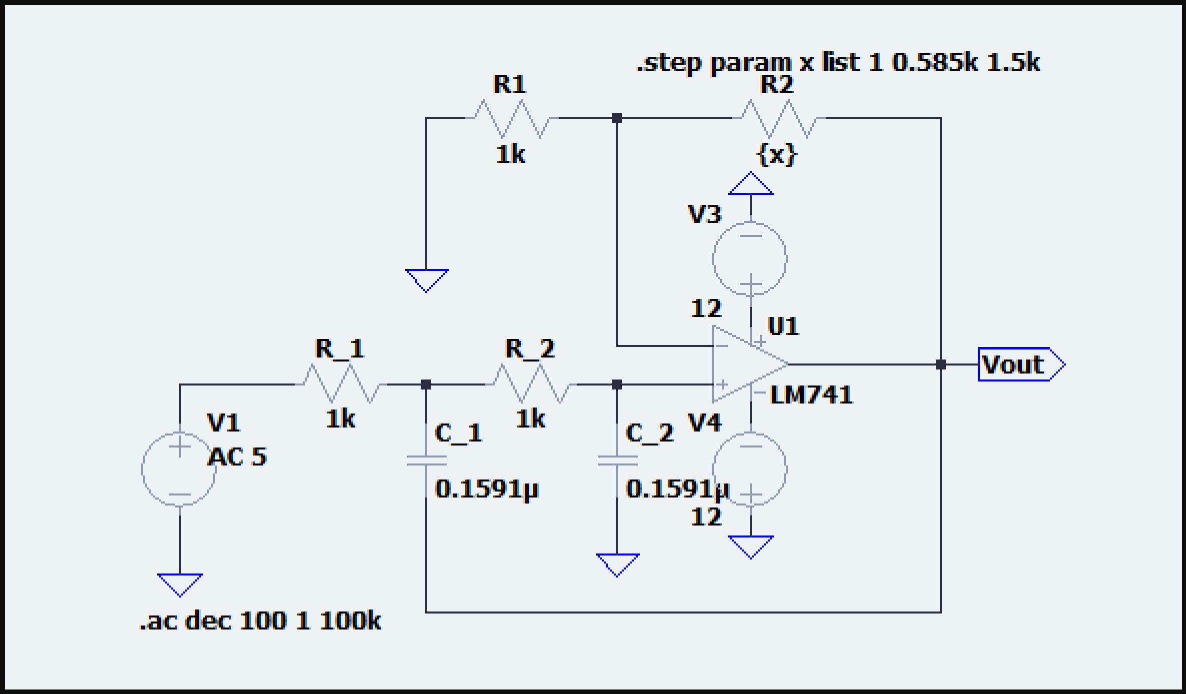
For Q=0.707,

K=1.585, R2=0.5855kΩ

For Q=2,

K=2.5, R2=1.5kΩ

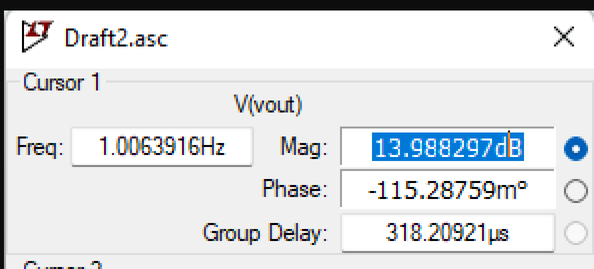
Circuit in LTSpice:

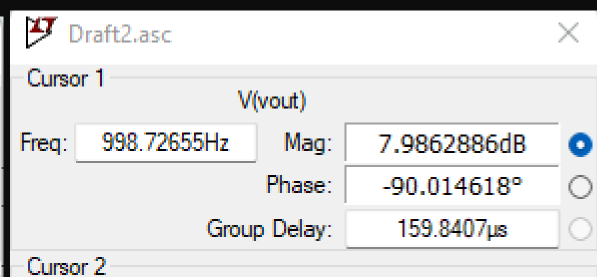


2. Simulate the circuit and obtain the frequency response. Determine the DC gain, the cut-off' frequency and stop-band roll-off and compare with the designed.

Frequency/phase Response:

For Q=0.5,





Gain = 13.988297dB

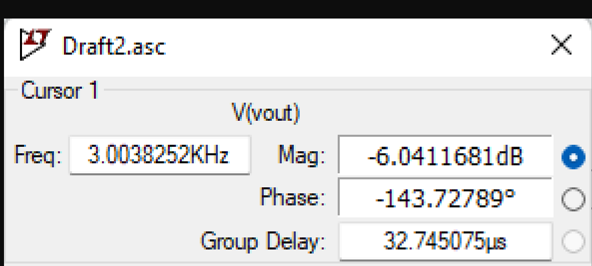
Fc= 998.72655Hz

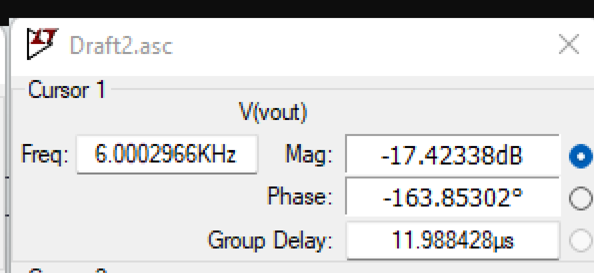
K=1, R2 has to be 0Ω.

Stop band roll-off

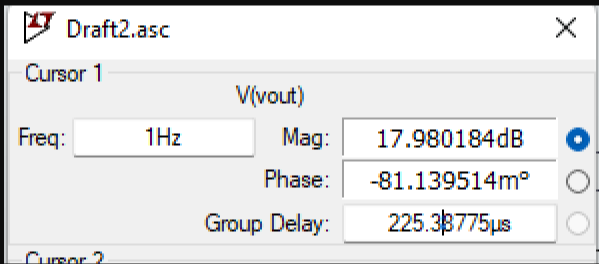
$= (-17.4233+6.041181)/((5.9926-3.0038)*10^3)$

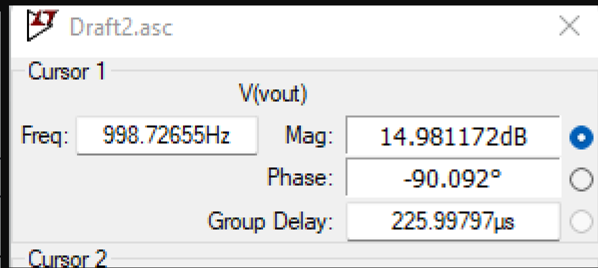
$= -0.036$





For Q=0.707,





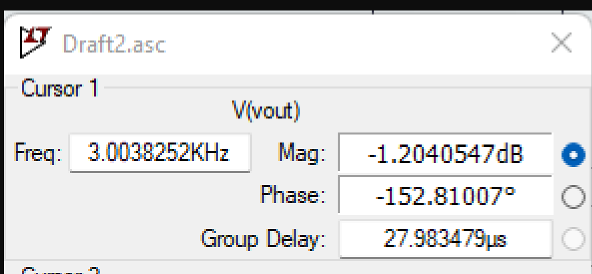
Gain = 17.980184dB

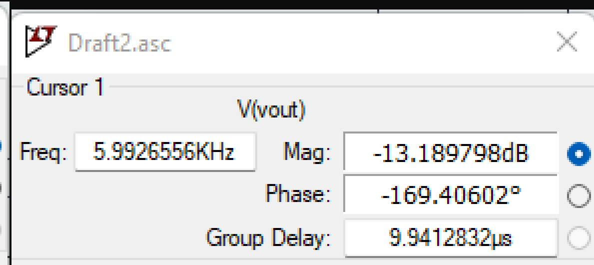
Fc= 998.72655Hz

Stop band roll-off

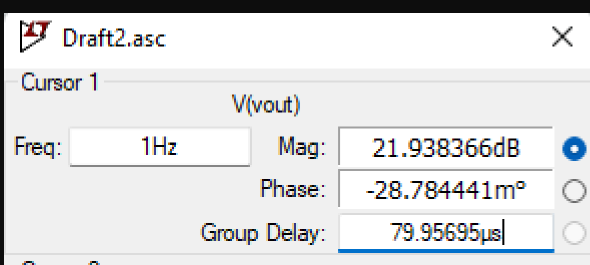
$= (-13.1897+1.2040)/((5.9926-3.0038)*10^3)$

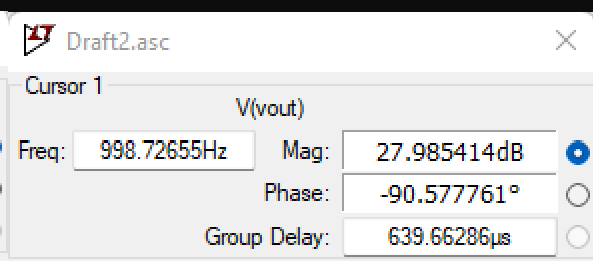
$=-0.038$





For Q=2,





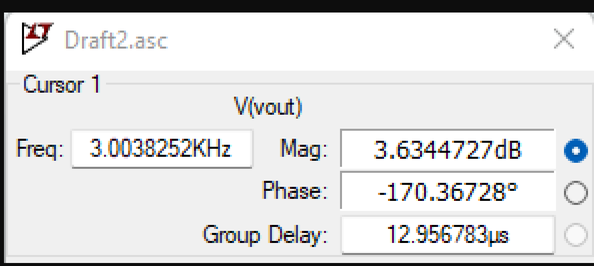
Gain = 21.938366dB

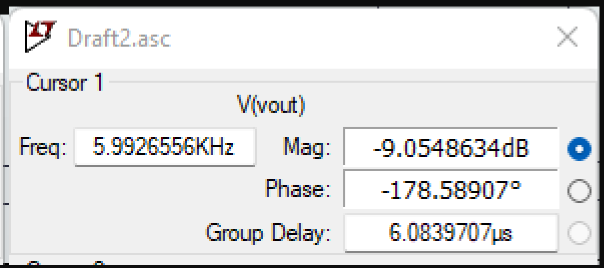
Fc= 998.72655Hz

Stop band roll-off

$= (-9.0548-3.6344)/((5.9926-3.0038)*10^3)$

$=-0.041$





$$F_{maxgain} = fc\sqrt{1-\frac{1}{2Q^2}} = 10^{3}*\sqrt{\frac{7}{8}} = 0.935 \text{ kHz}$$

$$|H(jw)|_{\text{max at Fmaxgain}} = \frac{QK}{\sqrt{1-\frac{1}{4Q^2}}} = \frac{5*4}{\sqrt{15}} = 5.16$$

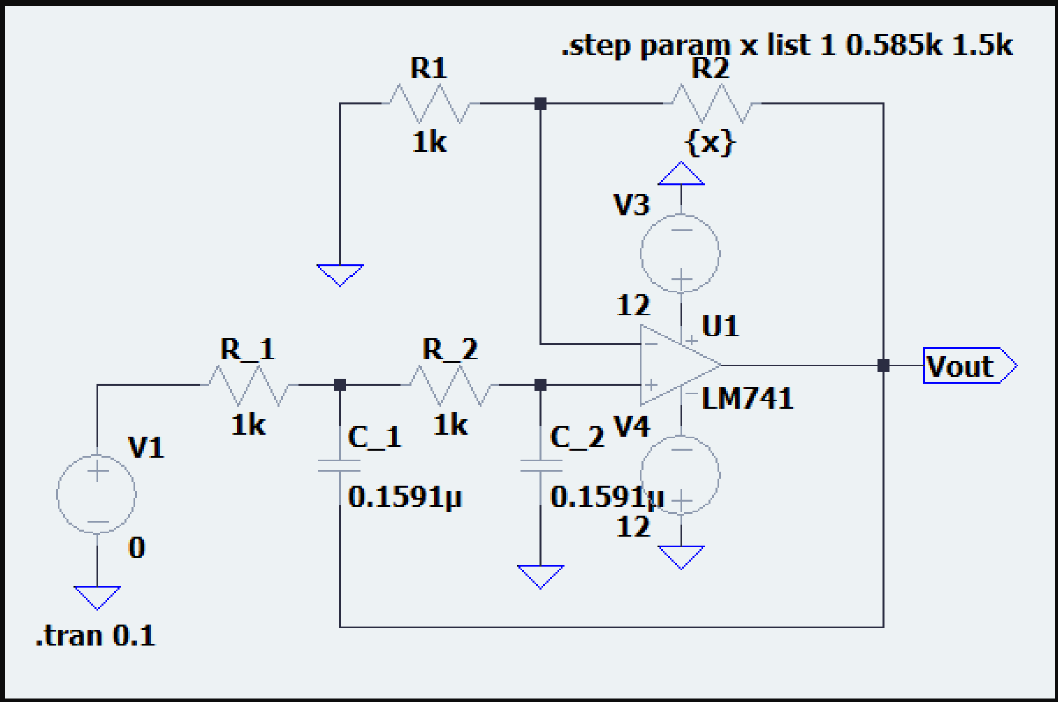
3.Tabulate the results in the format shown in Table 1 below.

Q	Ri	k	F0 Frequency at which gain = QK	Hp (max gain)	Fp Frequency at which max gain occurs	Stop band roll-off
0.5	1	2	998.72655	13.988297dB	1Hz	-0.036
0.707	0.585k	1.585	998.72655	17.980184dB	30.417337Hz	-0.038
2	1.5k	2.5	998.72655	28.275992dB	931.12805Hz	-0.041

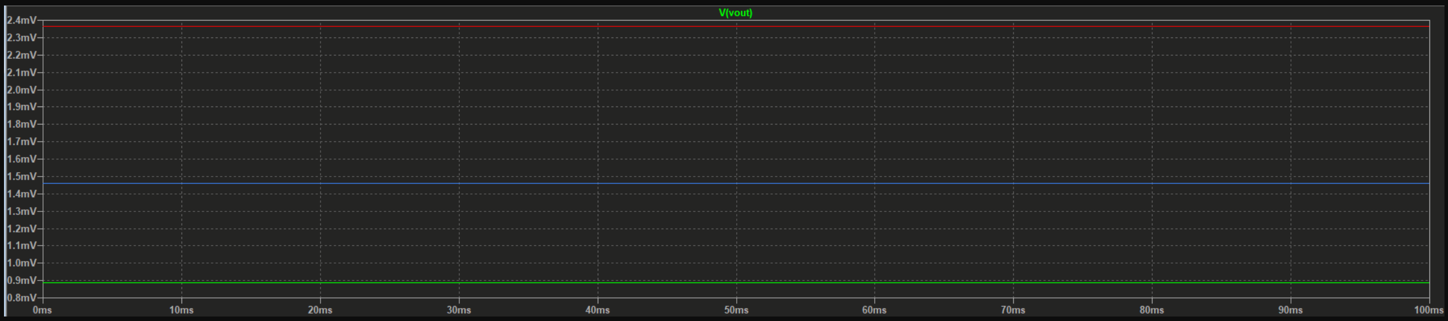
4. Now, ground the input terminal of the filter (Remember to disconnect the Signal Generator in the hardware lab). Adjust R2such that the gain K = (1+ R2/R1) becomes slightly higher than 3. You will see the filter oscillating. What is the reason?

Let K = 3.2, We get R= 2.2KΩ

Circuit in LTspice:



Observation: waveform:



When the gain value is greater than 3, the system become oscillatory because its tending towards system instability.

5. Convert the filter designed in step-1 to a high-pass filter. Observe and note down the salient features for Q = 0.707.

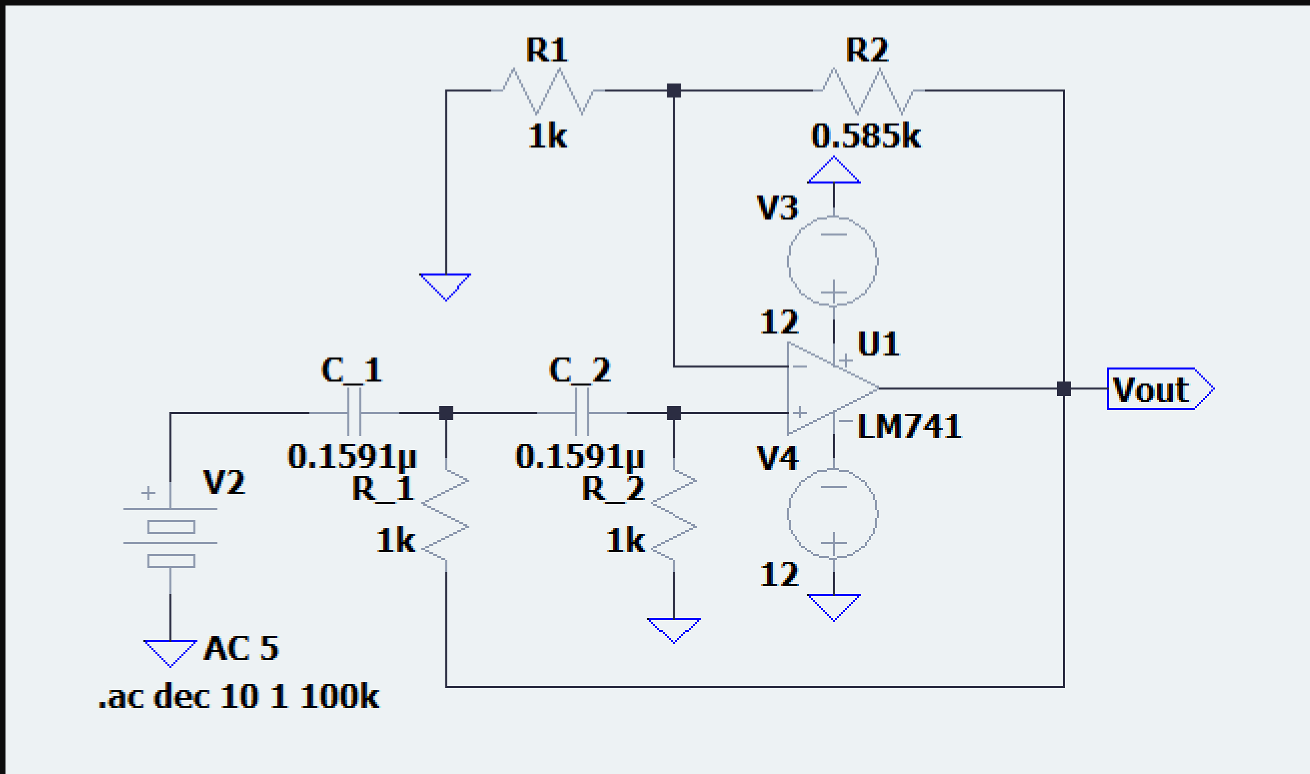
-> It can be easily made by just switching Capacitors and Resistors at the input.

As for Q=2, we will use the resistor values from above questions as it will be applicable here too.

Transfer Function for high pass filter $H(S) = \frac{K(RCS)^2}{(RCS)^2+(3-K)RCS+1}$

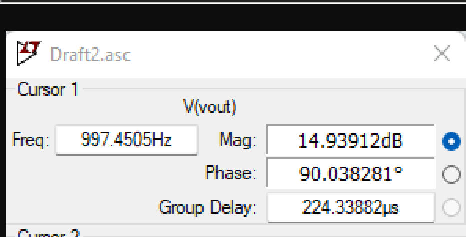
$f_{maxgain} = \frac{fc}{\sqrt{1-\frac{1}{2Q^2}}}$

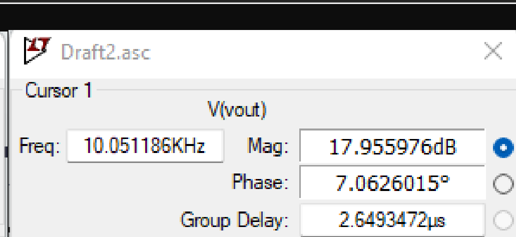
Circuit in LTspice:



Observations:

Frequency/phase Response:



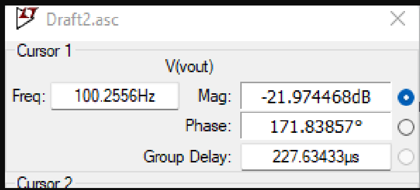


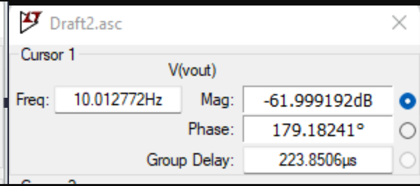
fc= 997.4505Hz

For roll off factor:

= (-21.974468+61.999192)/(100.2556-10.012772)

=0.44352249244





Hmax= 17.955976dB,

$f_{maxgain}$=10.0511 kHz

$$\text{fmax(expected)} = \frac{fc}{\sqrt{1-\frac{1}{2Q^2}}} = 1.00015 \text{ kHz}$$