NISARG UPADHYAYA
19CS30031 Nisarg

EXPERIMENT 4

ACTIVE LOW PASS FILTERS

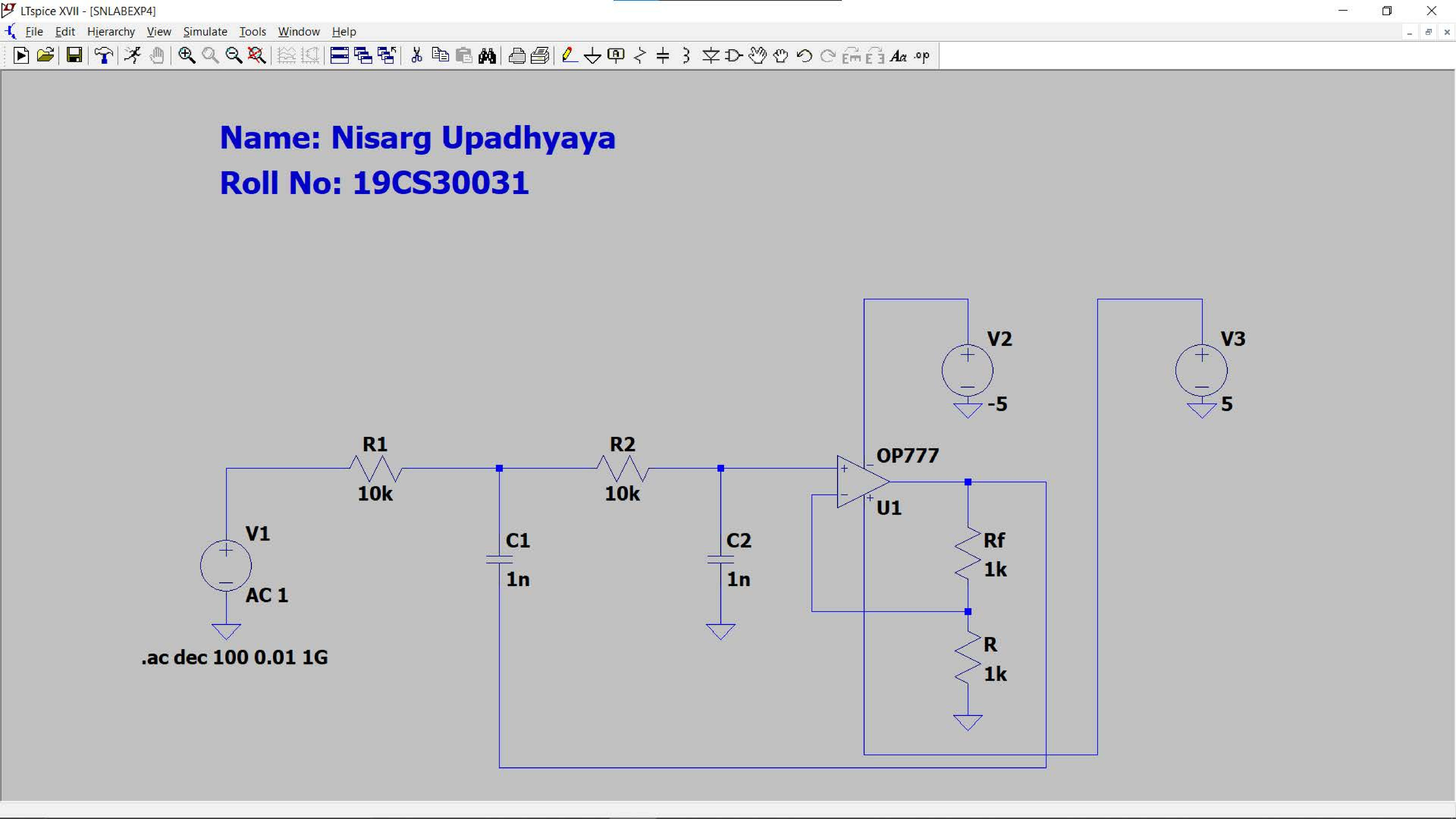
AIM

To familiarize with 2nd order Sallen Key active low pass filters and to measure their frequency responses.

REPORT

(1) LT Spice Circuit Diagram

Attached below.


LTspice XVII - [SNLABEXP4]
File Edit Hierarchy View Simulate Tools Window Help
Name: Nisarg Upadhyaya
Roll No: 19CS30031
V2
-5
V3
5
R1
10k
R2
10k
OP777
U1
V1
AC 1
C1
1n
C2
1n
Rf
1k
R
1k
.ac dec 100 0.01 1G

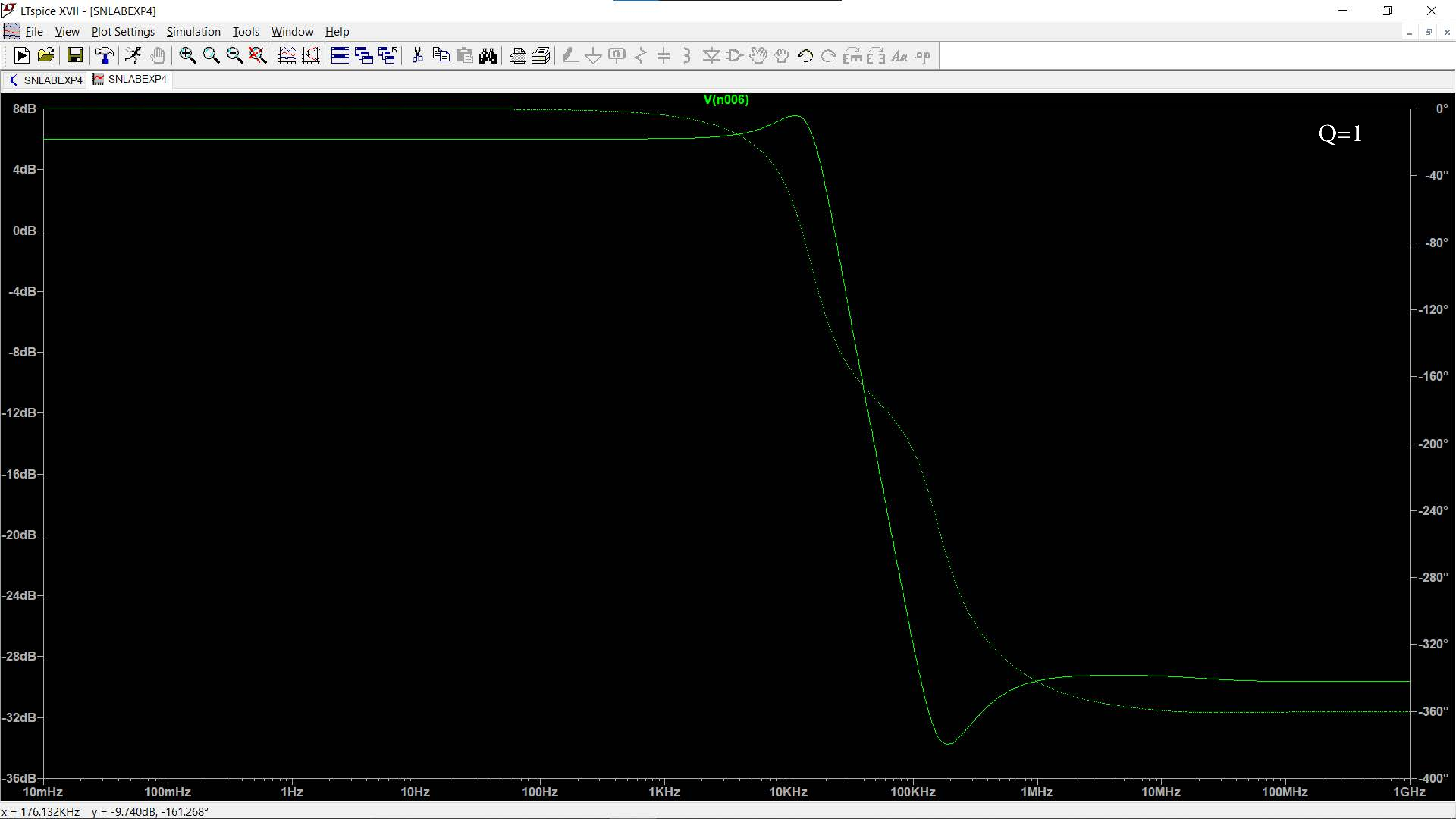
(2) $R_1 = R_2 = 10\,k\Omega$, $C_1 = C_2 = 1\,nF$, $Q = 1$

$$\Rightarrow Q = \frac{1}{3-K} = 1 \Rightarrow K = 2 \Rightarrow 1 + \frac{R_f}{R} = 2 \Rightarrow \frac{R_f}{R} = 1$$

Hence, we can chose $R = R_f = 1\,k\Omega$.

$$\Rightarrow f_0 = \frac{1}{2\pi\sqrt{C_1R_1C_2R_2}}\,Hz = \frac{1}{2\pi \times 10^4 \times 10^{-9}}\,Hz = \frac{10^5}{2\pi}\,Hz = 15915\,Hz$$

Experimentally the peak in gain is obtained around 11.3 kHz. The peak is not very sharp though owing to the low Q-factor. The transition is not very sharp.


LTspice XVII - [SNLABEXP4]
File View Plot Settings Simulation Tools Window Help
SNLABEXP4
SNLABEXP4
V(n006)
Q=1
8dB
4dB
0dB
-4dB
-8dB
-12dB
-16dB
-20dB
-24dB
-28dB
-32dB
-36dB
0°
-40°
-80°
-120°
-160°
-200°
-240°
-280°
-320°
-360°
-400°
10mHz
100mHz
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
x = 176.132KHz y = -9.740dB, -161.268°

(3) $Q = 1.5\ ,\ 2.5$

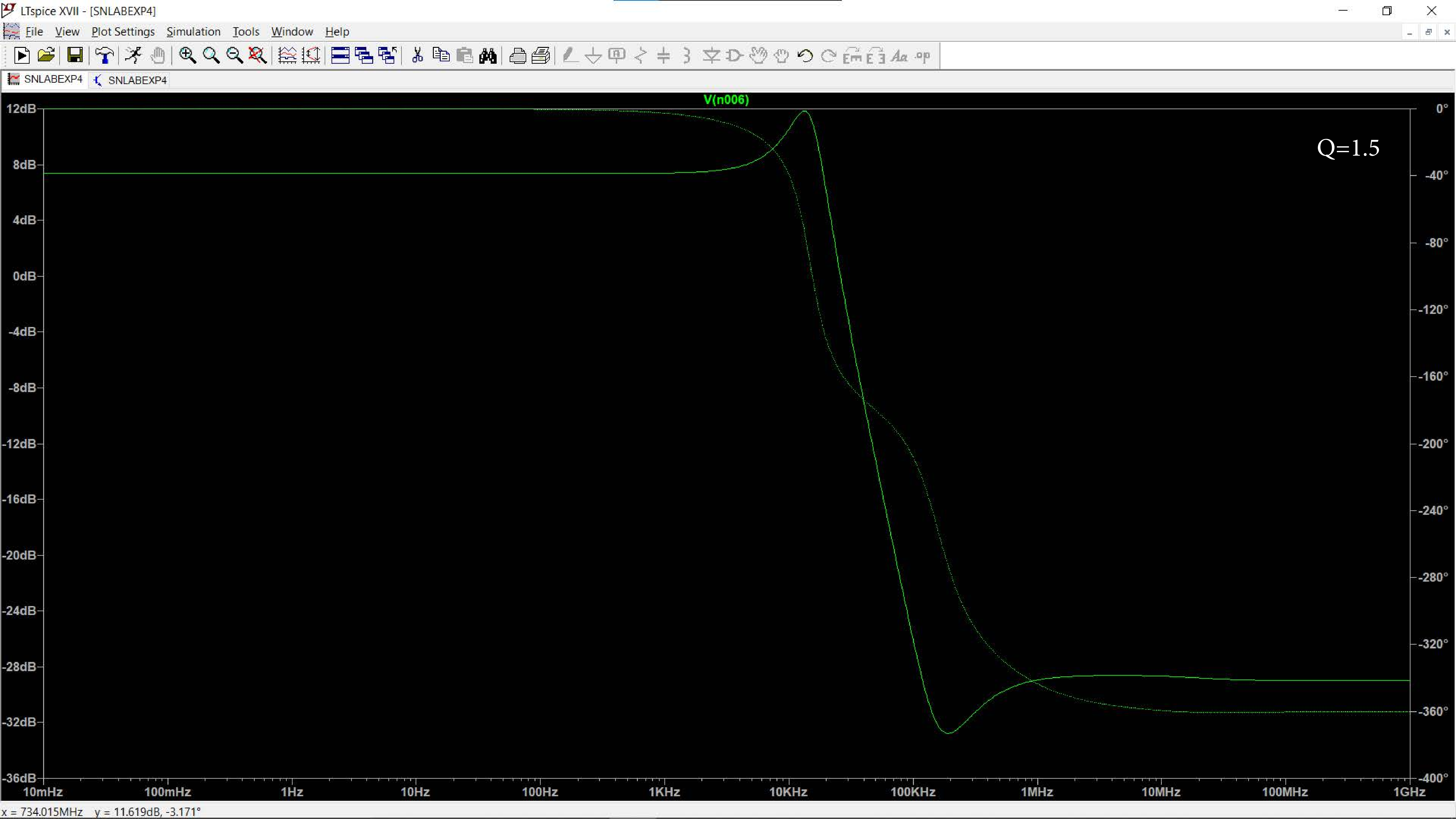
$$\Rightarrow Q = \frac{1}{3-K} = \frac{3}{2} \Rightarrow K = \frac{7}{3} \Rightarrow 1 + \frac{R_f}{R} = \frac{7}{3} \Rightarrow \frac{R_f}{R} = \frac{4}{3}$$

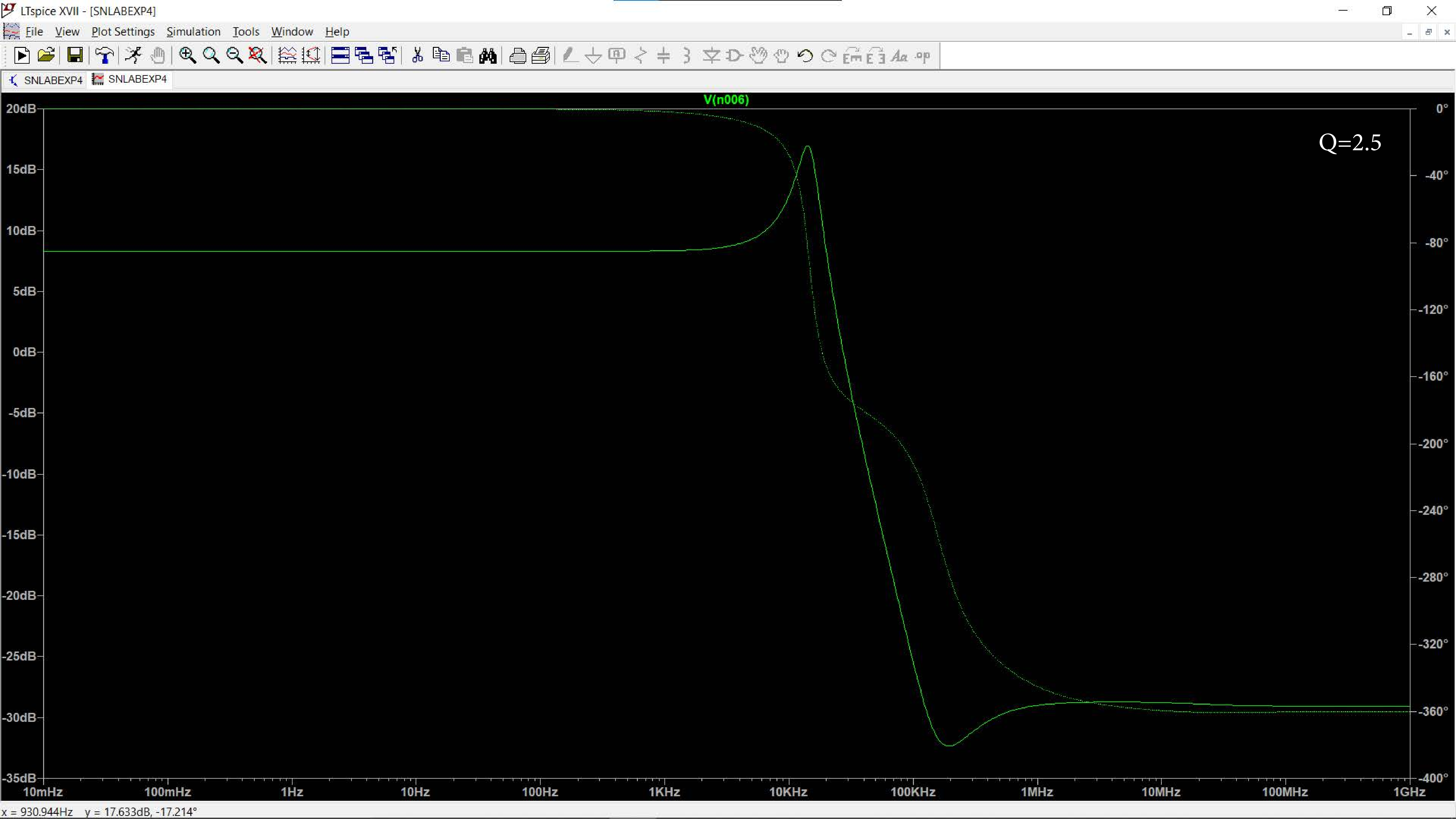
Hence, we can choose $R_f = 2k\Omega$ and $R = 1.5k\Omega$

$$\Rightarrow Q = \frac{1}{3-K} = \frac{5}{2} \Rightarrow K = \frac{13}{5} \Rightarrow 1 + \frac{R_f}{R} = \frac{13}{5} \Rightarrow \frac{R_f}{R} = \frac{8}{5}$$

Hence, we can choose $R_f = 2k\Omega$ and $R = 1.25k\Omega$.

As expected, when we increase the Q-factor the sharpness of the peak increases. The filter now offers a much sharper transition. The peak in gain now occurs around a frequency of 14.5 kHz. Also the initial fall (roll off) after the peak is much steeper than for $Q = 1$. Thus this offers a comparitively higher selectivity.


LTspice XVII - [SNLABEXP4]
File View Plot Settings Simulation Tools Window Help
SNLABEXP4
SNLABEXP4
V(n006)
Q=1.5
12dB
8dB
4dB
0dB
-4dB
-8dB
-12dB
-16dB
-20dB
-24dB
-28dB
-32dB
-36dB
0°
-40°
-80°
-120°
-160°
-200°
-240°
-280°
-320°
-360°
-400°
10mHz
100mHz
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
x = 734.015MHz y = 11.619dB, -3.171°


LTspice XVII - [SNLABEXP4]
File View Plot Settings Simulation Tools Window Help
SNLABEXP4 SNLABEXP4
V(n006)
Q=2.5
20dB
15dB
10dB
5dB
0dB
-5dB
-10dB
-15dB
-20dB
-25dB
-30dB
-35dB
0°
-40°
-80°
-120°
-160°
-200°
-240°
-280°
-320°
-360°
-400°
10mHz
100mHz
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
x = 930.944Hz y = 17.633dB, -17.214°

NISARG UPADHYAYA
19CS30031 Nisarg

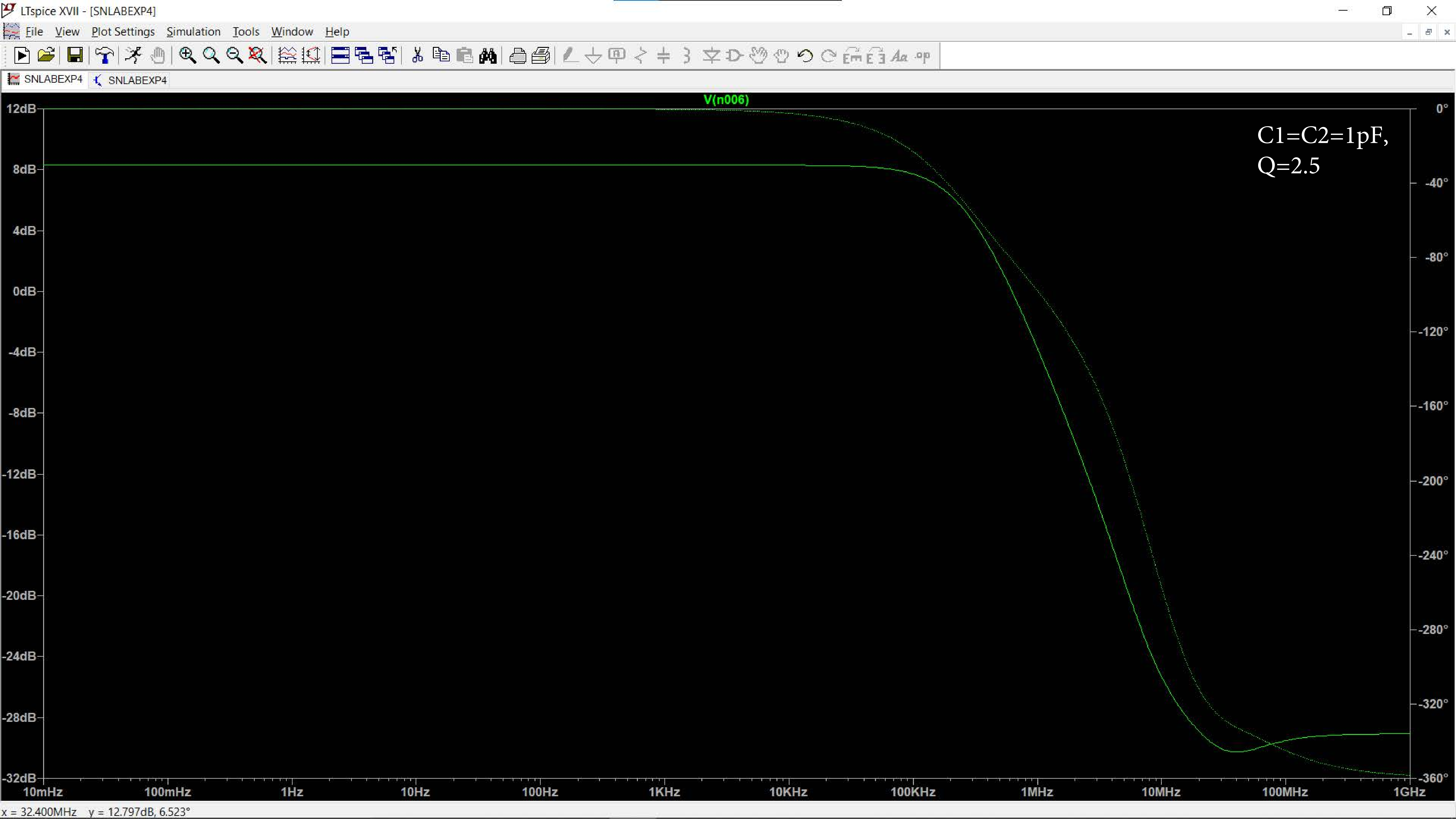
(4) $R_1 = R_2 = 10 k\Omega$, $C_1 = C_2 = 1 nF$, $Q = 2.5$

$$\Rightarrow Q = \frac{1}{3-K} = \frac{5}{2} \Rightarrow K = \frac{13}{5} \Rightarrow 1 + \frac{R_f}{R} = \frac{13}{5} \Rightarrow \frac{R_f}{R} = \frac{8}{5}$$

Hence we can choose $R_f = 2 k\Omega$ and $R = 1.25 k\Omega$

$$\Rightarrow f_0 = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}} Hz = \frac{1}{2\pi RC} Hz = \frac{10^8}{2\pi} Hz = 15915 kHz$$

Experimentally the gain starts to drop around 150 kHz and reaches -3dB value near 300kHz. The huge difference between theoretical and experimental value stems from the fact that the op-amp used (OP-777) has a finite bandwidth. (non ideal) Moreover this bandwidth is much lesser (for the OP-AMP used) than 15915 kHz. Due to this the OP-AMP deviates from its ideal behaviour. It can be observed by using a different OP-AMP such as LT-1226 the roll-off occurs near the expected value.


LTspice XVII - [SNLABEXP4]
File View Plot Settings Simulation Tools Window Help
SNLABEXP4
SNLABEXP4
V(n006)
C1=C2=1pF,
Q=2.5
12dB
8dB
4dB
0dB
-4dB
-8dB
-12dB
-16dB
-20dB
-24dB
-28dB
-32dB
0°
-40°
-80°
-120°
-160°
-200°
-240°
-280°
-320°
-360°
10mHz
100mHz
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz
x = 32.400MHz y = 12.797dB, 6.523°