1 Question 1:

1.1 Low pass filter Output:

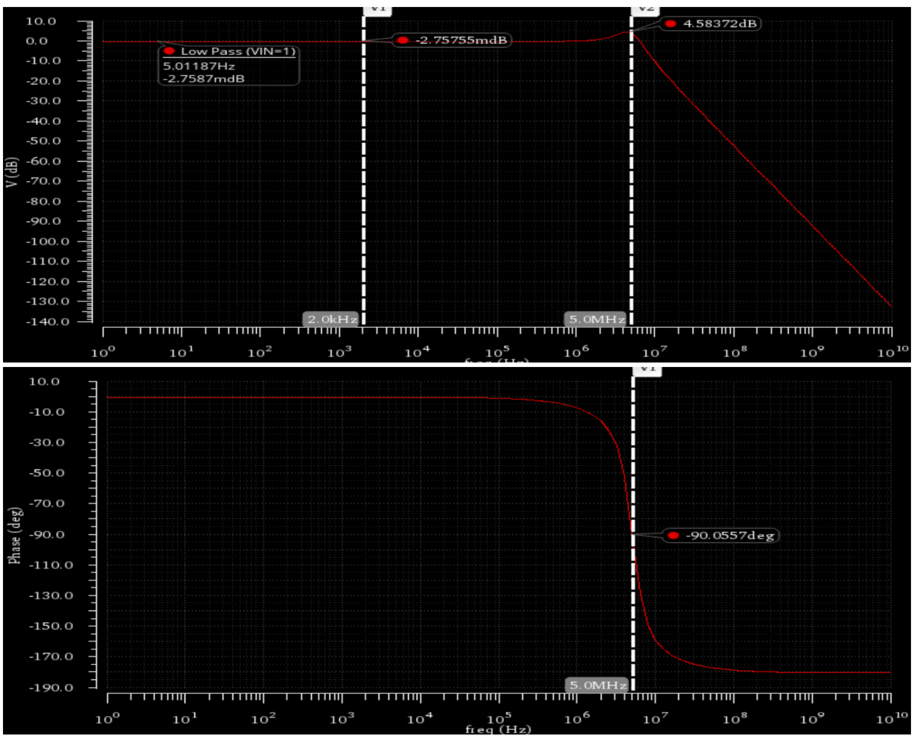

Figure 1. LPF magnitude and phase response

H_0 : DC gain $\quad = 1$ (0dB)

Q: Quality factor $= 1.7$ (4.6 dB) , Can be calculated from peak value $= H_0 Q$

f_0: Peaking frequency $=$ 5MHz (or frequency at 90° phase)

1.2 High Pass filter response

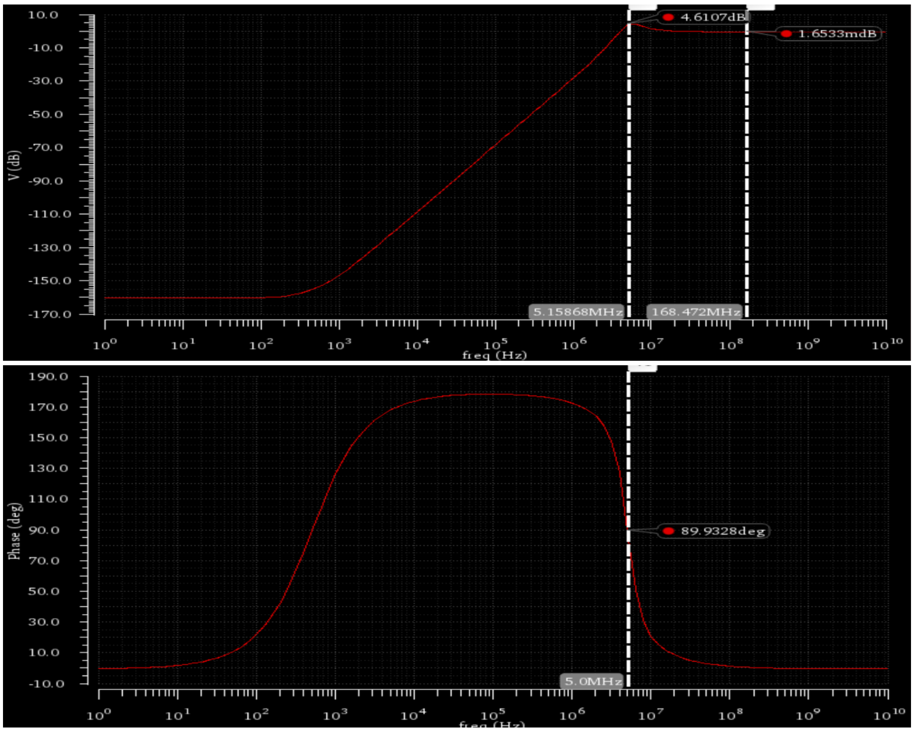

Figure 2. HPF magnitude and phase response

H_0: gain at high frequency $= 1$ (0dB)

Q: Quality factor $= 1.7$ (4.6dB), (peak gain $= H_0Q$)

$f_0 = 5$MHz , (fequency at peak gain or frequency at $90°$ phase shift)

1.3 Band Pass filter response

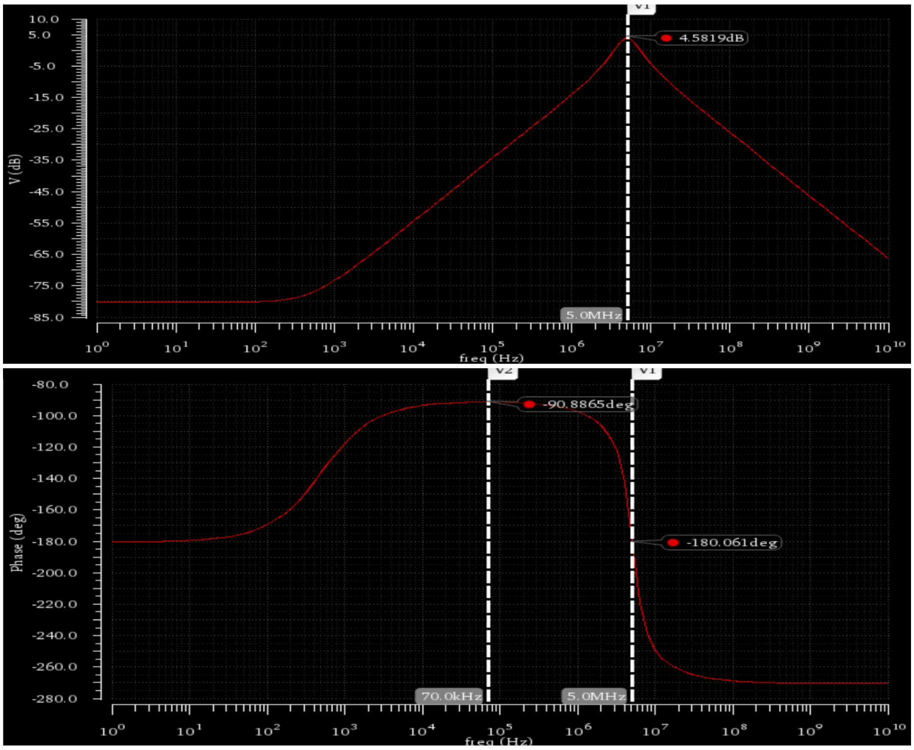

Figure 3. BPF magnitude and phase response

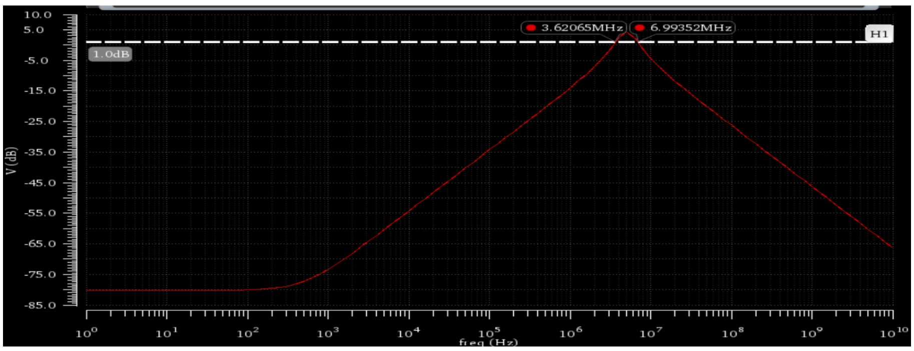

Figure 4. BPF Bandwidth Estimation

f_0: Resonance frequency (frequency at peak magnitude) = 5MHz

$Q = \frac{f_0}{\mathrm{BW}} = \frac{5M}{3M} = 1.67\,(\approx 1.7)$

$H_0 = \frac{H_{\max}}{Q} = 4.58\mathrm{dB} - 4.6\mathrm{dB} \approx 0\mathrm{dB} = 1$

1.4 Band Stop filter

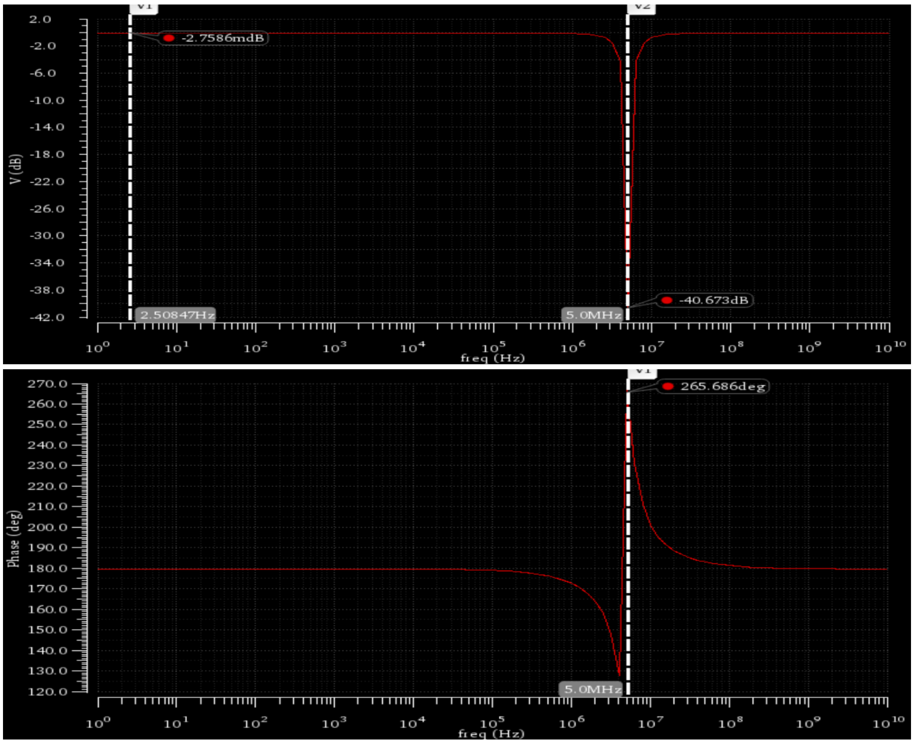

Figure 5. BSF magnitude and phase response

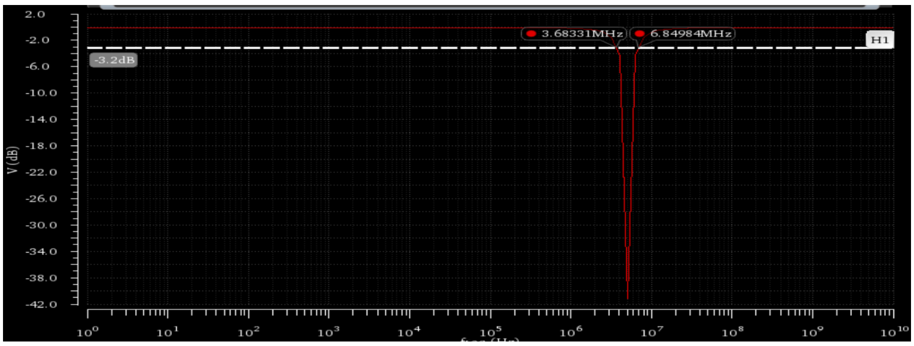

Figure 6. BSF Bandwidth

H_0: gain at DC = 1 (0dB)

f_0: frequency at the notch $f_0 = 5\mathrm{MHz}$

$Q = \frac{f_0}{\mathrm{BW}} = \frac{5}{3.1} = 1.6\,(\approx 1.7)$

2 Transient Analysis

2.1 Sinwave Input

2.1.1 1MHz input

Applying a sin wave with amplitude 1

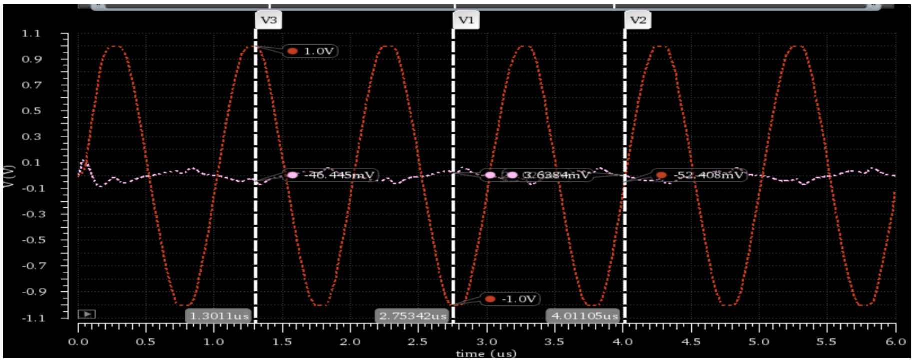

Figure 7. Sine wave input for LPF(Red) and HPF (white) at 1MHz

For low pass filter $|v_{\text{out}}| = 1$, which is expected since $w < w_0$

Phase shift = 1.25u-1.3/1u * 360 = $-18°$

For High pass filter: $|v_{\text{out}}| << 1$, which is expected since $w < w_0$

2.1.2 5MHz input

Input signal amplitude = 500mv

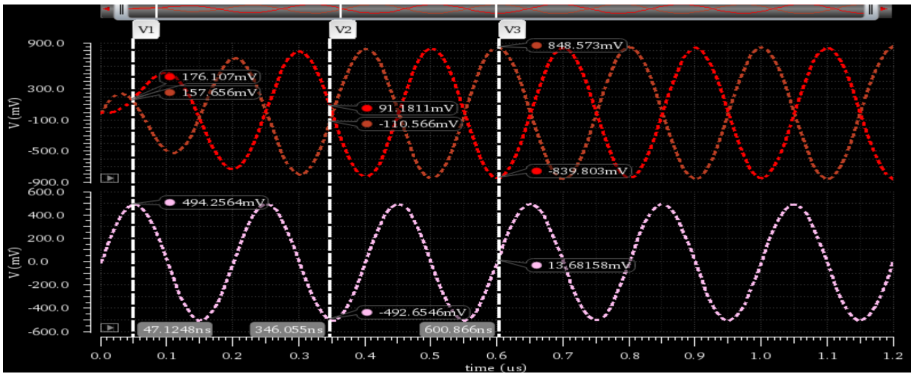

Figure 8. Sinusoidal response for LPF(red) and HPF(orange) , input(white),5MHz

Both High pass and low pass have approximatly equal amplitude as expected 1.7*vin = 0.85, but for Low pass filter phase shift = -90 and high pass filter = +90.

2.1.3 10 MHz input

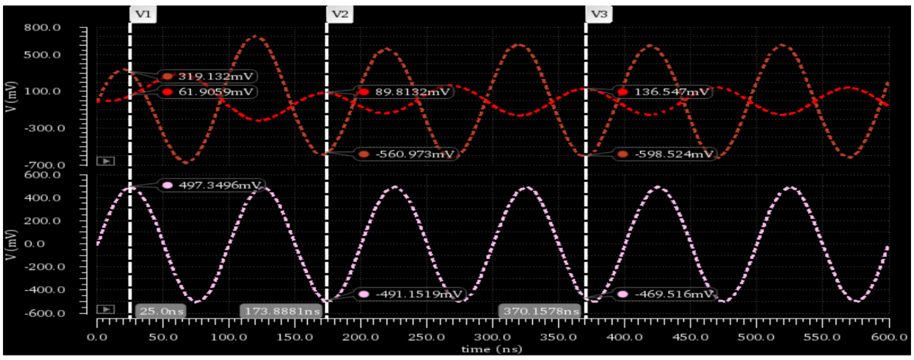

Figure 9. inusoidal response for LPF(red) and HPF(orange) , input(white), 10MHz

For LPF output, it begins to attenuate as expected and phase shift is close to 180 degrees, for HPF output gain goes closer to unity and phase shift gets closer to 0 degree.

2.2 Square wave input

2.2.1 1MHz input

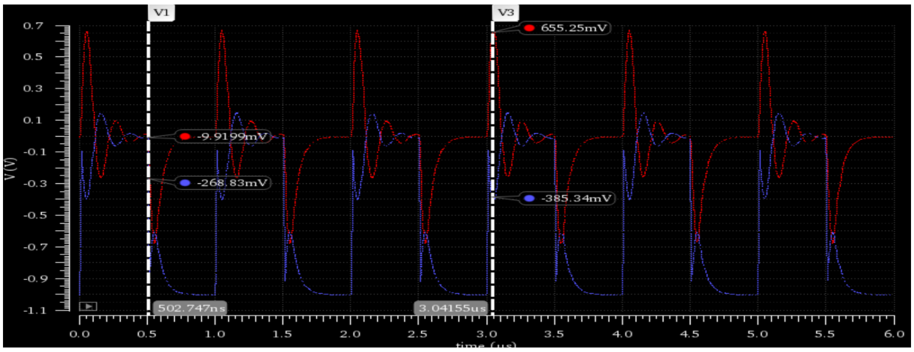

Figure 10. Bandpass (red) and Bandstop (blue) outputs

A signal with frequency 1MHz is not in the pass band of the bandpass filter, but since it's a square wave signal, the sharp transition contains high order harmonics which some of them is in the passband , those harmonics (5MHz harmonic) get amplified with gain close to 4.6dB as shown in figure.

For the bandstop the operation is opposite , high order hamonics in the sharp transistion get damped making the output like an output of Low pass filter.

Overshoots and ringing ocurr because (Q=1.7) > 0.5.

2.2.2 5MHz input

square wave input amplitude = 1V

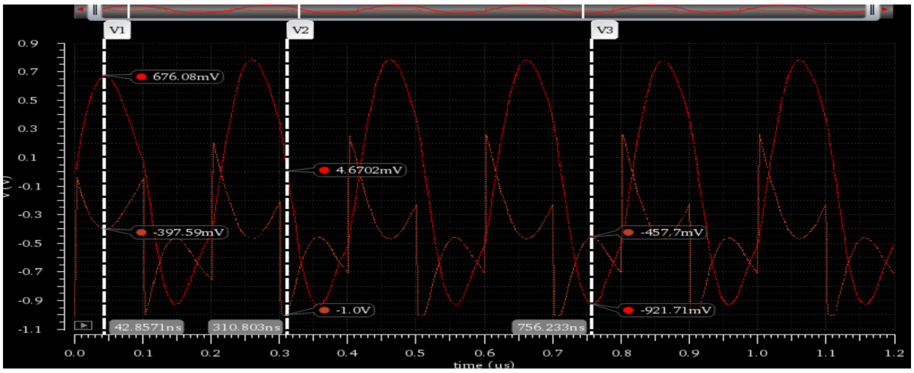

Figure 11. Bandpass output (red) and bandstop (orange) 5MHz

For bandpass : at 5MHz input square wave , bandpass filter filters higher order harmonics leaving the output signal with only the fundamental frequency of the input square wave, that's why the output is a sine wave.

For bandstop: the operation is opposite to the bandpass it attenuates the fundamental frequency at 5MHz and multiplies higher order harmonics with unity.

2.2.3 10 MHz input

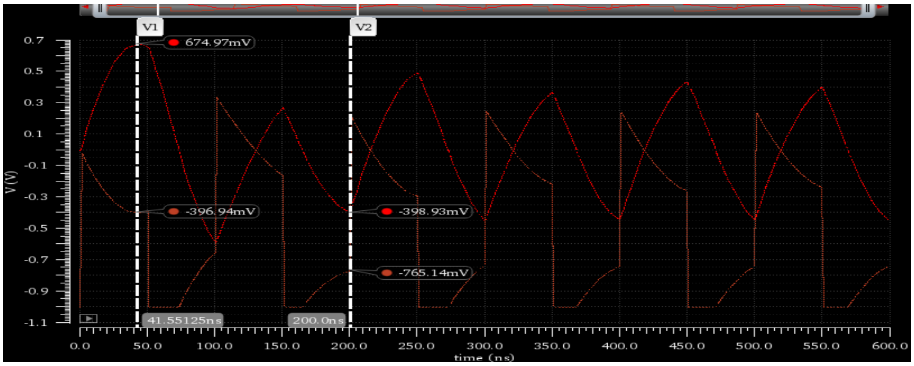

Figure 12. Bandpass output (red) and bandstop (orange) 10MHz

For BandPass filter : At a fundamental frequency out of the pass band , the bandpass filter behaves like an integrator (Low pass filter) thi make the output like a triangle wave

For the Bandstop filter: the operation is opposite, the filter behave as a differentiator (High pass filter) sharp transitions has higher gain than flat part.

3 Non-ideal response

In case of OPamps Has a limited bandwidth 5MHz.

3.1 Sinwave case

3.1.1 LPF

For 1MHz input sinwave , it's effect will be minimum for the amplitude(since Bandwidth = 5MHz), but maybe it will increase the phase shift.

For 5MHz input sinwave, output amplitude will be smaller by maybe 6dB (Two more poles at 5MHz) or more.

For 10MHz input sinwave , output will get attenuated more.

3.1.2 HPF:

For 1MHz sin input , it's effect is minimum and output is attenuated as before.

For 5MHz input, instead of being 4.6dB , it will be less because of the added poles at 5MHz.

For 10MHz input , instead of 0dB , output will be much more less because of the limited bandwidth of the Opamp.

3.2 Square wave input

3.2.1 Bandpass filter

For 1MHz square wave input, since the BW of the opamp is in the passband of the filter, this would make the passband a little useless, this would reduce the overshoots and the output will be near zero

For 5MHz input , since passband maybe the output would be like a sinwave but with much lower amplitde.

For 10MHz input , the output will be more like a triangle with lower amplitudes

3.2.2 Bandstop filter

For 1MHz input, Overshoots will be reduced and the output will be more like a Low pass filtered sin wave.

For 5MHz input , Fundamental frequency will be attenuated more but higher order harmonics will be also get attenuated.

For 10MHz output wouldn't get high gain because of the limited bandwidth.