EE2703 Assignment 7 - Circuits with Sympy

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Abstract

In this assignment, LTI circuits were analysed with Laplace Transforms using Sympy. The detailed process and observations from each of the plots is given below.

Step Response of Low Pass Filter

The step response of the low pass filter was found by applying $\frac{1}{s}$ as input. The function sm_to_sp() is used to convert the Sympy expression to a Scipy-friendly form (numerator+denominator).

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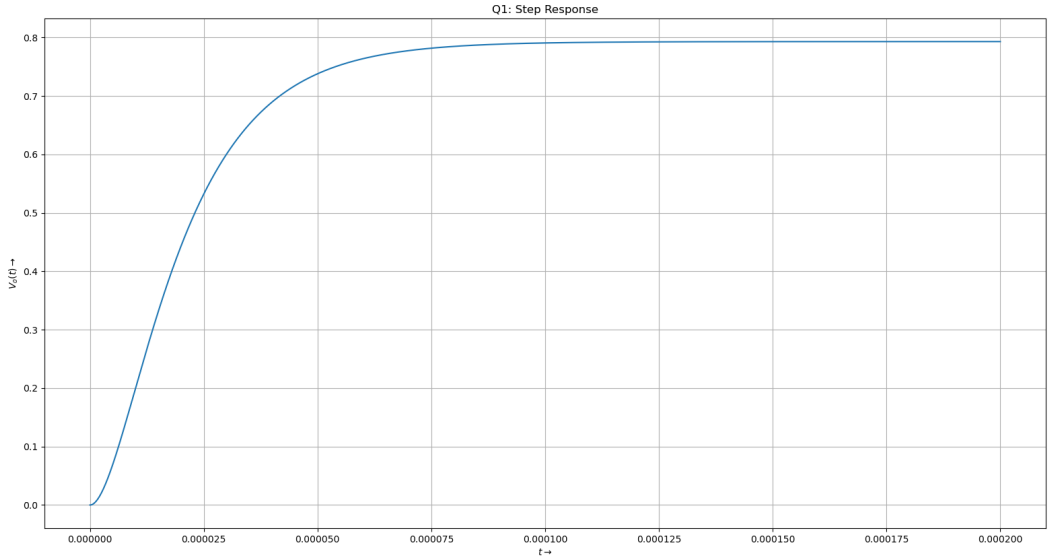
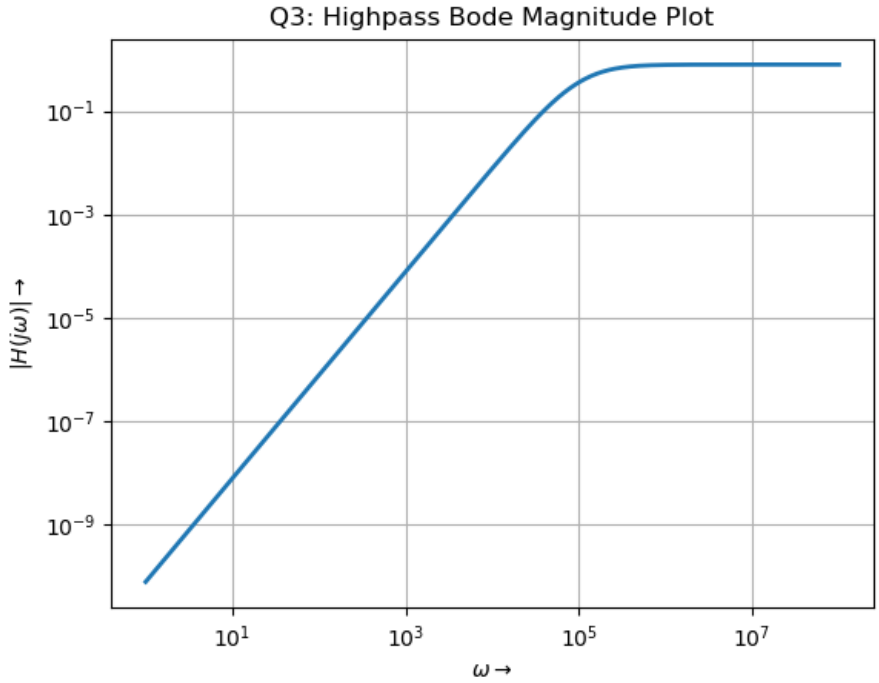
A,b,V = lowpass(10000,10000,1e-9,1e-9,1.586,1/s)
Vo = V[3]
H = sm to sp(Vo)
```



The response starts from zero, then increases to its steady state value around 0.8. The change in input at t=0 from 0 to 1 can be considered a high frequency component, and since this is a low pass filter, this component is attenuated. The steady input after this change can be considered low frequency, and it passes without attenuation. The amplitude is 0.8 due to the construction of the circuit – it is the maximum gain of this filter across all frequencies

Analysis of High Pass Filter

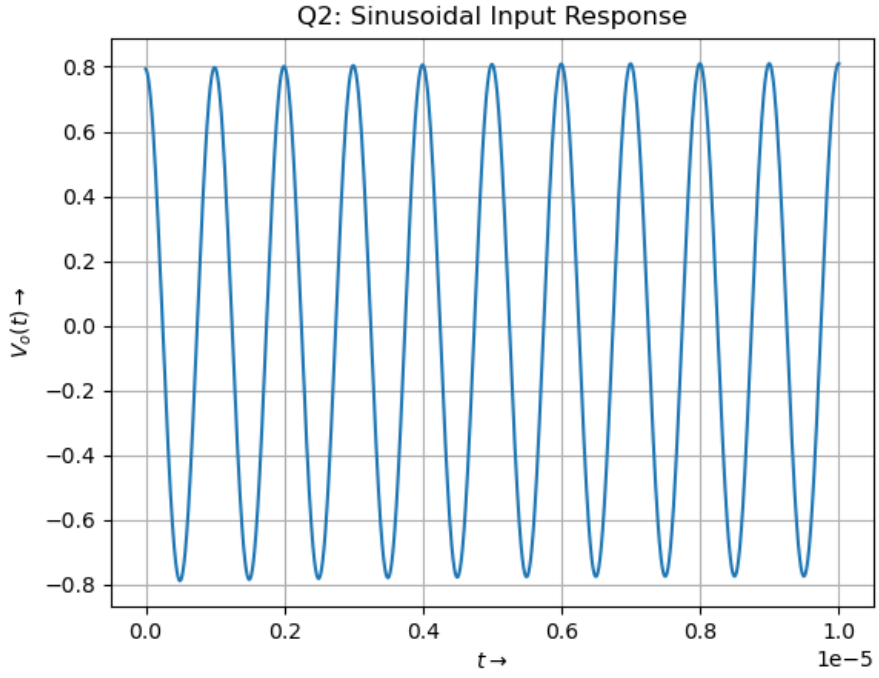
The Bode plot of the High pass filter was found using the method detailed in the question paper, and is given below



The curve has a slope of 20db/decade at low frequencies, and flat at high frequencies, indicating the presence of a single pole around 1e5.

Response of High Pass Filter to Mixed Sinusoid

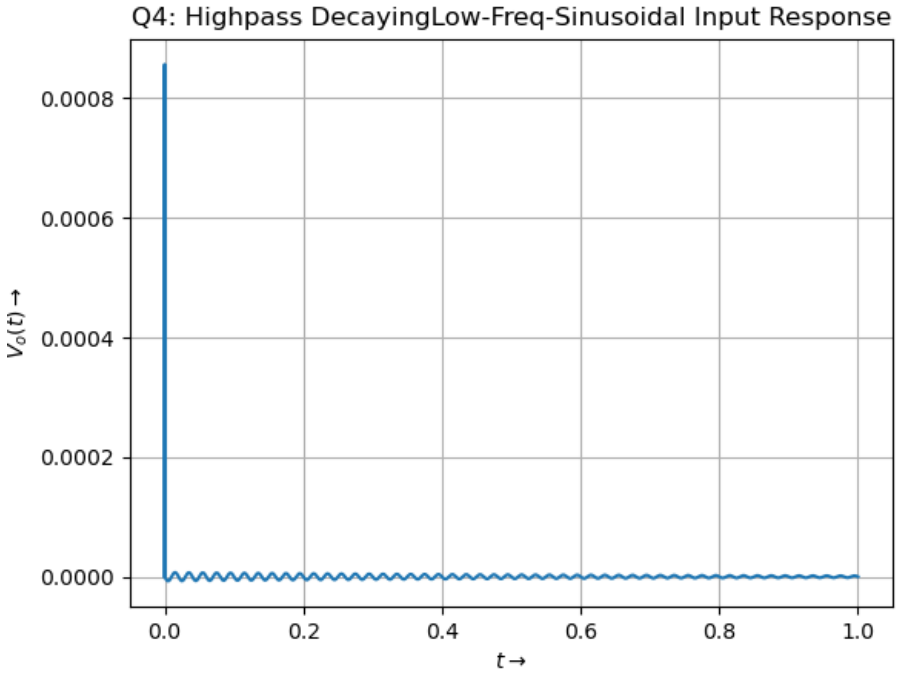
A mixed sinusoid of two frequencies, 2e3 and 2e6, is passed into the highpass filter. Since the attenuation of the low frequency was too much, the output has been plotted on the high frequency timescale.

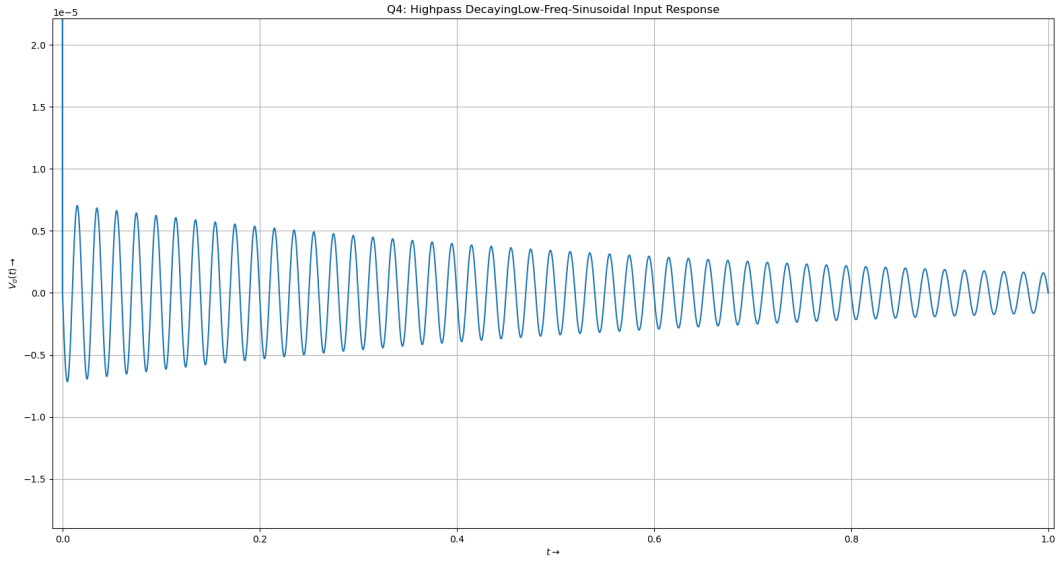


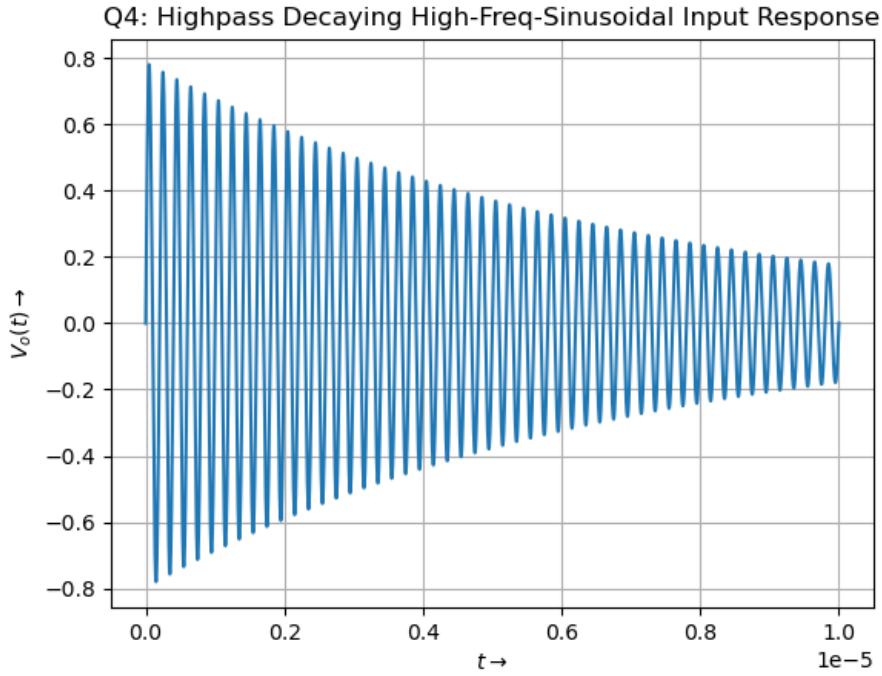
Response of High Pass Filter to Decaying Sinusoids

A low frequency and a high frequency sinusoid were passed as input.
The low frequency response has been attenuated by about 1e-5, while the high frequency response is

unattenuated. The amplitudes of both decay exponentially.
The low frequency plot has been zoomed to show decaying nature. The unzoomed plot is to show the initial peak



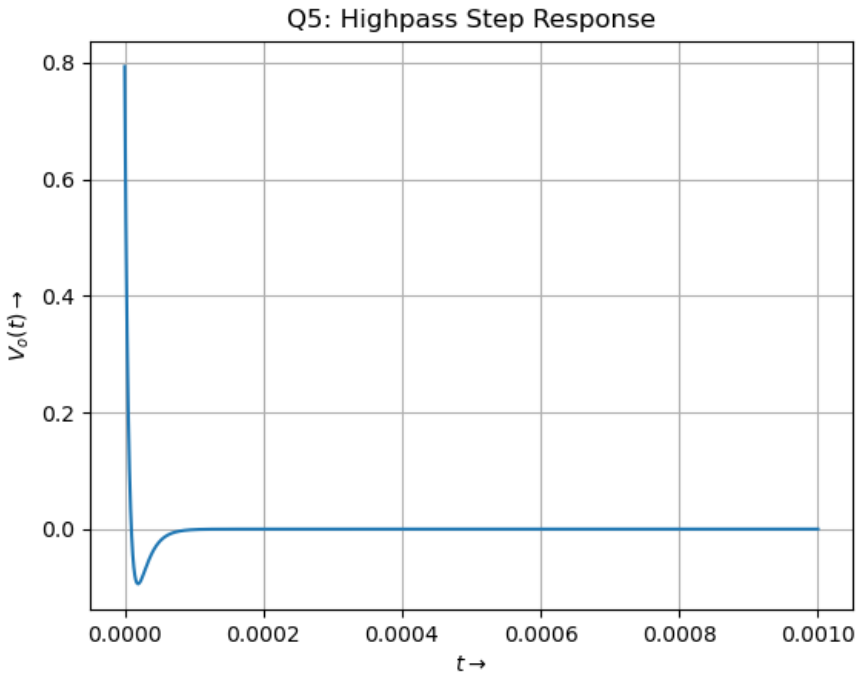




The low frequency plot has a peak near the beginning, much higher than the amplitude. This is due to the transients in the system.

Step Response of High Pass Filter

The step response starts with a peak, then overshoots to negative, and then settles at 0 steady state. One way to think of this is – the change from 0 to 1 can be considered as a high frequency component, while the constant 1 after the switch can be considered a low frequency component. Since it is a high pass filter, it allows the 0-1 change component to pass, but attenuates the constant-1 component since it is low frequency.



Conclusion

This assignment explored the analysis of LTI circuits using Sympy in Python. Briefly, the following results were obtained

- Q1: In step response of LPF, the start is low, it increases like exponential curve, then settles to a DC value (0.8). This gives us the DC gain of the LPF. The shape of the curve is because the 0-1 change is attenuated by LPF. A single pole system gives an exponential after inverse laplace
- Q2: When a sum of high and low frequency sinusoids are passed to HPF, the high frequency component is preserved while the low frequency is attenuated.
- Q3: The HPF was analyzed using Bode plot. Since the slope was +20dB/dec till 1e5, and then flat, the system has one pole around 1e5 and one zero around 0. The HPF attenuates low frequencies and passes high ones
- Q4: The response to high frequency damped sinusoid is as expected – exponentially decaying amplitudes over time. The initial amplitude is unattenuated since it is HPF. The low frequency sinusoid also shows the same features, but the amplitude is attenuated by the filter by around 1e-5. There is also an initial peak reaching 0.8, this is due to the transient response of the system.
- Q5: Step response starts high, and then overshoots, and then decays till 0 at steady state. With similar logic as LPF step response, the 0-1 change passes without attenuation since it is high frequency, while the constant-1 after is low frequency, and is attenuated. The physical interpretation comes from capacitors being shorted at high frequencies.