# EE2703: Assignment 7

Gugulothu Naveen

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## 1 Introduction

This week's assignment involves the analysis of filters using laplace transforms. Python's symbolic solving library, sympy is a tool we use in the process to handle our requirements in solving Modified Nodal Analysis equations. Besides this the library also includes useful classes to handle the simulation and response to inputs.

Coupled with scipy's signal module, we are able to analyse both High pass and low pass filters, both second order, realised using a single op amp

## 2 Assignment

### 2.1 Low pass Filter

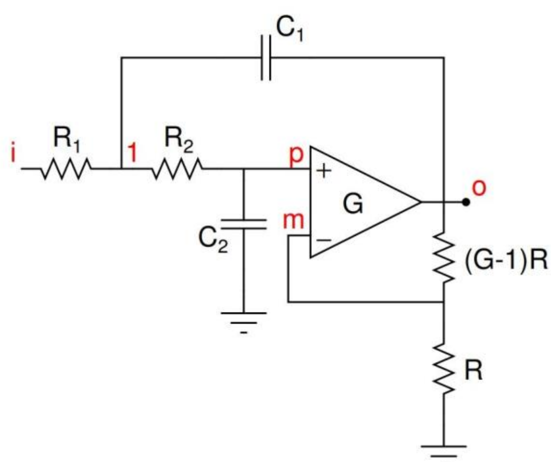


Figure 1: A Lowpass Filter

The low pass filter we use gives the following matrix after simplification of Modified Nodal Equations.

$$\begin{bmatrix} 0 & 0 & 1 & -1/G \\ \frac{-1}{sR_2C_2} & 1 & 0 & 0 \\ 0 & -G & G & 1 \\ \frac{-1}{R_1} - \frac{1}{R_2} - s*C_1 & \frac{1}{R_2} & 0 & sC_1 \end{bmatrix} \begin{bmatrix} V_1 \\ V_p \\ V_m \\ V_o \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{-V_i(s)}{R_1} \end{bmatrix}$$

The magnitude bode plot for the filter looks like:

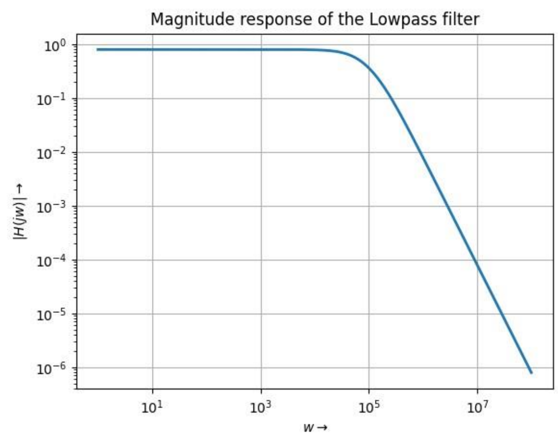


Figure 2: Lowpass filter magnitude response

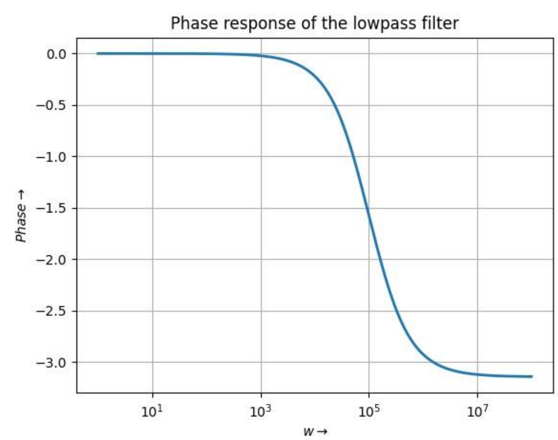


Figure 3: Lowpass filter phase response

The unit step response for the low pass filter:

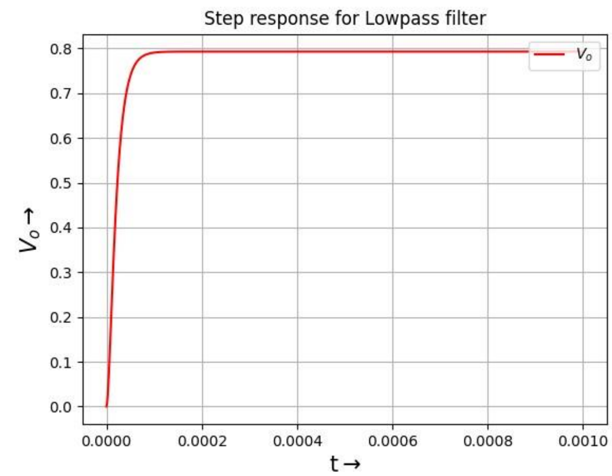


Figure 4: Step response for Lowpass filter

## 2.2 Response of Lowpass Filter to mixed freq sinusoid

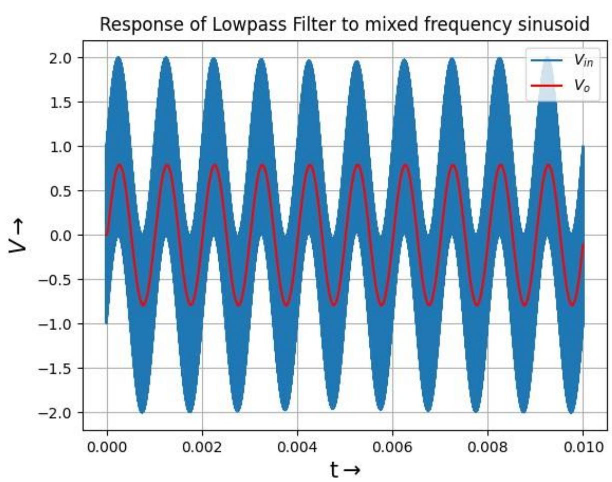


Figure 5: Response of Lowpass Filter to mixed freq sinusoid

We notice that the high frequency part has been attenuated.

## 2.3 High pass Filter

The high pass filter we use gives the following matrix after simplification of Modified Nodal Equations.

$$\begin{bmatrix} 0 & -1 & 0 & 1/G \\ \frac{s*C_2*R_3}{1+s*C_2*R_3} & 0 & -1 & 0 \\ 0 & G & -G & 1 \\ -s*C_2-\frac{1}{R_1}-s*C_1 & 0 & s*C_2 & \frac{1}{R_1} \end{bmatrix} \begin{bmatrix} V_1 \\ V_p \\ V_m \\ V_o \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -V_i(s)*s*C_1 \end{bmatrix}$$

The magnitude bode plot for the filter looks like:

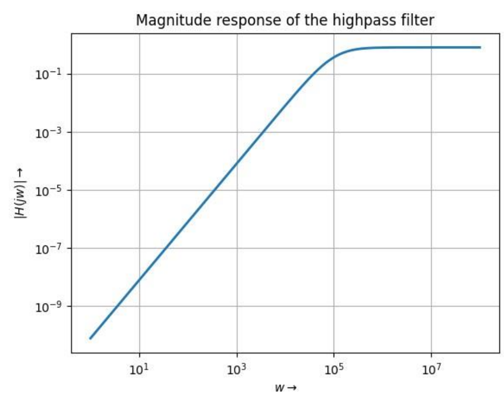


Figure 6: High pass filter magnitude response

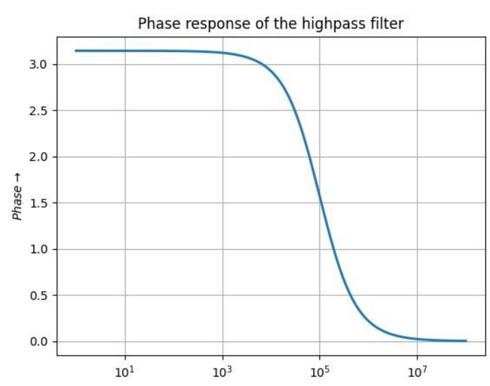


Figure 7: High pass filter phase response

## 2.4 Response of Highpass filter to a damped sinusoid

### 2.4.1 Low frequency damped sinusoid

The Low frequency damping sinusoid is given by:

$$f(t) = sin(2\pi 10^3 t) * e^{-1000t} \tag{1}$$

It is expected that it will be fully attenuated by the high pass filter while it will pass through the Low pass filter with almost no change.

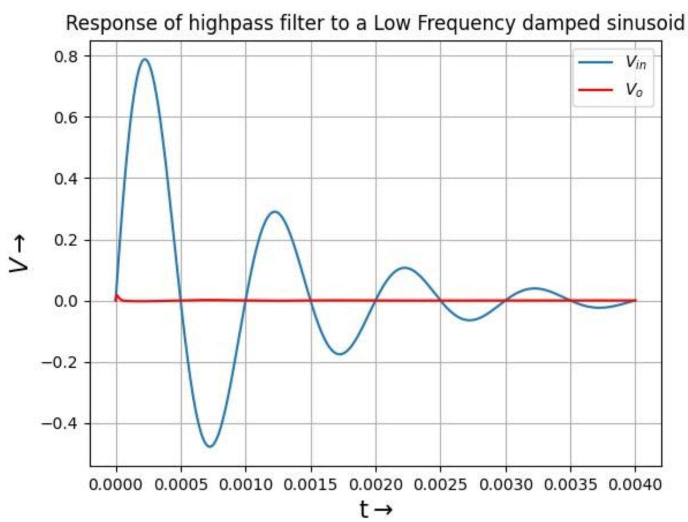


Figure 8: Response of Highpass filter to a Low Frequency damped sinusoid

The high pass filter responds by quickly attenuating the input. Notice that the time scales show that the high pass filter response is orders of magnitudes faster than the low pass response. This is because the input frequency is below the cutoff frequency, so the output goes to 0 very fast.

### 2.4.2 High frequency damped sinusoid

The High frequency damping sinusoid is given by:

$$f(t) = sin(2\pi 10^6 t) * e^{-100000t} \tag{2}$$

It is expected that it will be fully attenuated by the Low passs filter while it will pass through the high pass filter with almost no change.

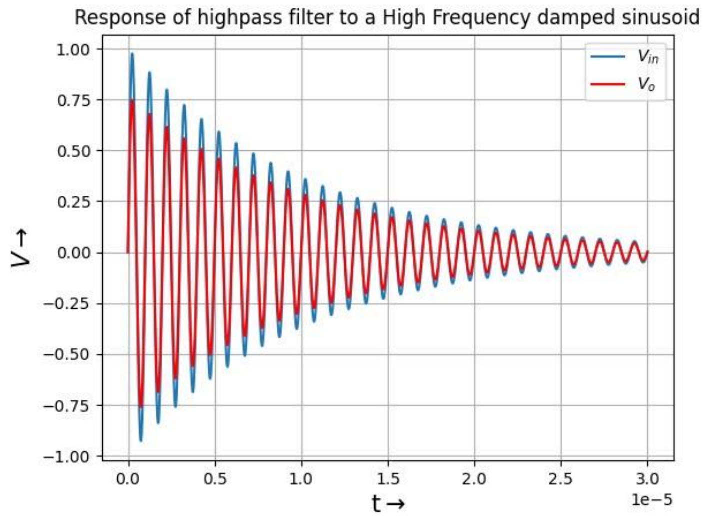


Figure 9: Response of Highpass filter to a High Frequency damped sinusoid

## 2.5 Response of Highpass filter to a unit step function

The unit step response, as expected is high at t=0 when there is an abrupt change in the input. Since there is no other change at large time values outside the neighbourhood of 0, the Fourier transform of the unit step has high values near 0 frequency, which the high pass filter attenuates.

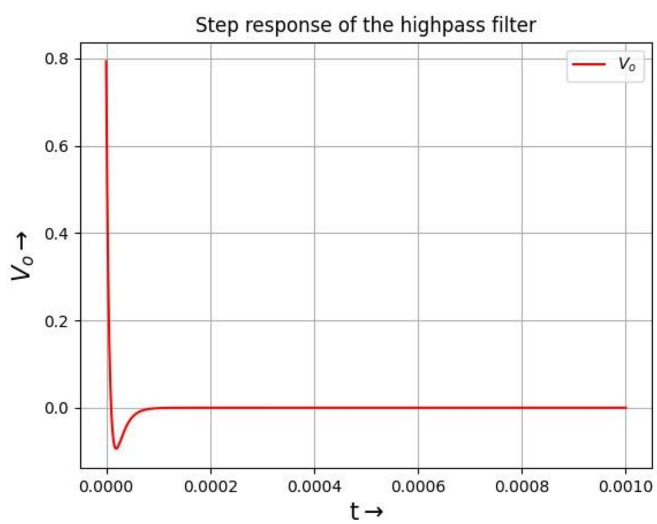


Figure 10: Step response of highpass filter

# 3 Conclusion

- Output response of Lowpass Filter to mixed frequency sinusoid shows that the Lowpass filter passes only the low frequency component and almost completely attenuates the high frequency part, as expected. • From the step-response, of the low pass filter, it is seen that, at steady state, output is a constant value (at a very low attenuation). This is because, low pass filter will pass DC signals , and at time t much greater 0, step input is a DC input. At t = 0, though the rise is gradual, as the capacitors themselves take time to charge, and once they have done, the output becomes DC.

- Output response of Highpass filter to a damped sinusoid shows that it attenuates the low frequency damped sinusoid, while allow the high frequency damped sinusoids such as $10^6$ Hz as they are above the cut-off frequency. Also note that the change in the exponential would only affect the rate at which the sinusoid amplitude decays to zero.
- From the step-response of the high pass filter, it is seen that at t much greater than 0, output is 0. This is because, at these instants, input is a DC value and the high pass filter will attenuate this, and thus output will be almost 0. At t = 0, though, there is a peak for the output. This is because, at this point of discontinuity in the input, as seen from the frequency domain, a lot of high frequency components would be there, hence these would be passed, and so, an output is observed only at this point.