Assignment 8 : Circuit Simulation using sympy

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April 27, 2021

Introduction

In this assignment, we solve circuits using the sympy and scipy.signal modules in python.

1 Question 1

In order to find the step response of the lowpass filter, we first need to define the system. The following code implements a lowpass filter

```
def lowpass(R1, R2, C1, C2, G, Vi):
    s = sy.symbols('s')
    A = sy.Matrix([[0,0,1,-1/G], [-1/(1+s*R2*C2),1,0,0], [0,-G,G,1], [-1/R1-1/R2-s*C1,1/R2,0,s*C1]])
    b = sy.Matrix([0,0,0,-Vi/R1])
    V = A.inv()*b
    return A, b, V
```

Since the system is an expression in s, the following piece of code is used to convert it into an object that can be used by the signal toolbox

```
def TFconverter(h):
    s = sy.symbols('s')
    n, d = sy.fraction(h)
    N = sy.Poly(n, s).all_coeffs()
    D = sy.Poly(d, s).all_coeffs()
    N, D = [float(f) for f in N], [float(f) for f in D]
    return sp.lti(N, D)
```

The step response is found by using lsim() and is plotted in Figure 1.

2 Question 2

The given input is

$$v_i(t) = (sin(2000\pi t) + cos(2 \times 10^6 \pi t))u_0(t)$$

The response to this input should be a signal with low frequency, since the high frequecies are blocked by the LPF. The response is given in Figure 2.

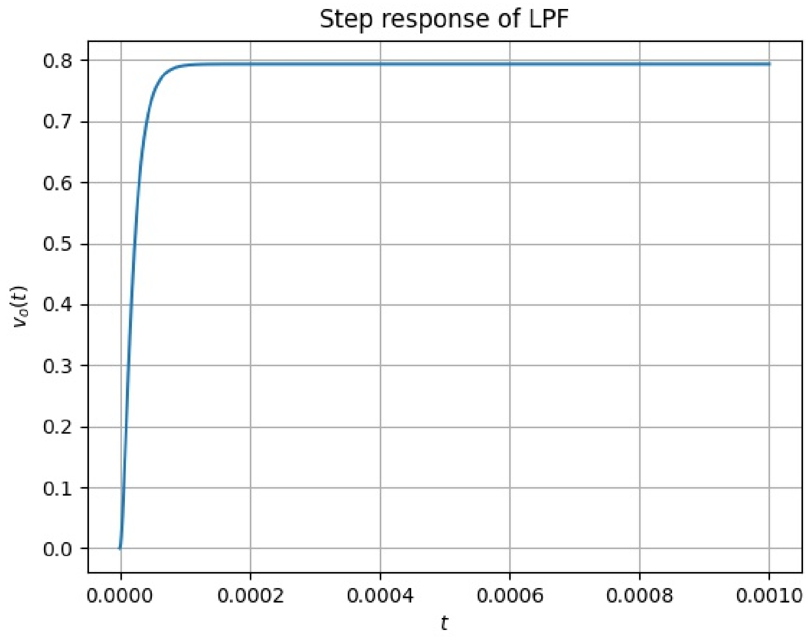

Figure 1: Step Response of Lowpass Filter

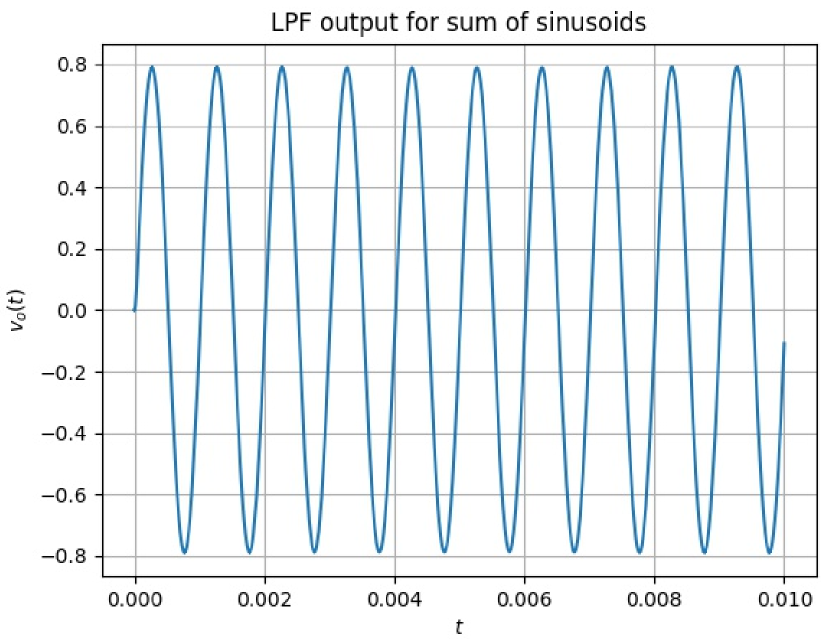

Figure 2: LPF response to sum of sinusoids

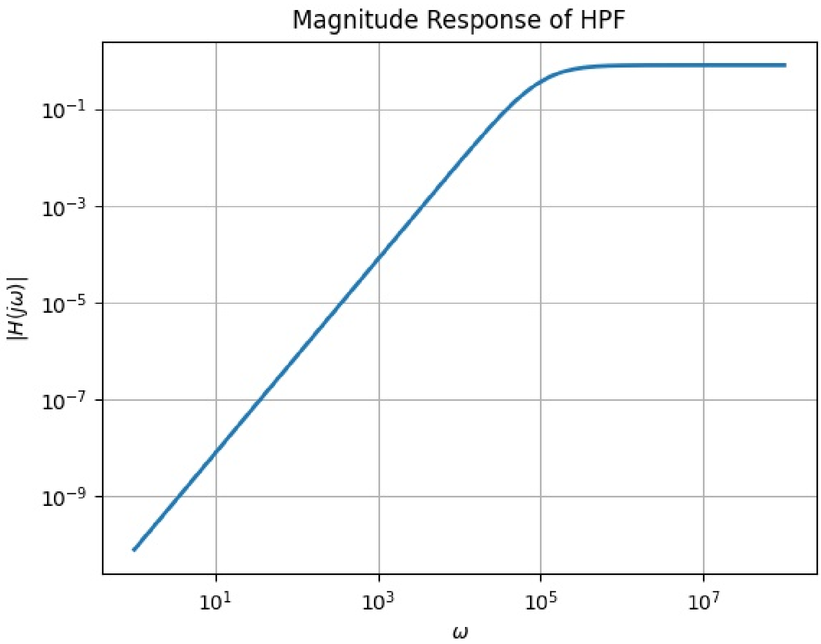

Figure 3: Magnitude Response of HPF

3 Question 3

In this section we simulate a highpass filter. The system is defined using the code given below

```
def highpass(R1, R2, C1, C2, G, Vi):
    s = sy.symbols('s')
    A = sy.Matrix([[0,-1,0,1/G], [s*C2*R2/(s*C2*R2+1),0,-1,0], [0,G,-G,1], [-1/R1-s*C1-s*C2,0,s*C2,1/R1]])
    b = sy.Matrix([0,0,0,-Vi*s*C1])
    V = A.inv()*b
    return A, b, V
```

The magnitude response of the filter is shown in Figure 3.

4 Question 4

In this section, we observe the response of HPF to damped sinusoids. We consider two sinusoids, one with low frequency and the other with high frequency. The decay is the same for both sinusoids. The sinusoids are

$$e^{-1000t}cos(2\times10^{6}\pi t), e^{-1000t}cos(2000\pi t)$$

The responses of the Highpass filter for these signals are given in Figures 4 and 5.

5 Question 5

The step response of the HPF is given in Figure 6. The fourier transform of $u(t)$ is given as

$$U(j\omega)=\frac{1}{j\omega}+\pi\delta(\omega)$$

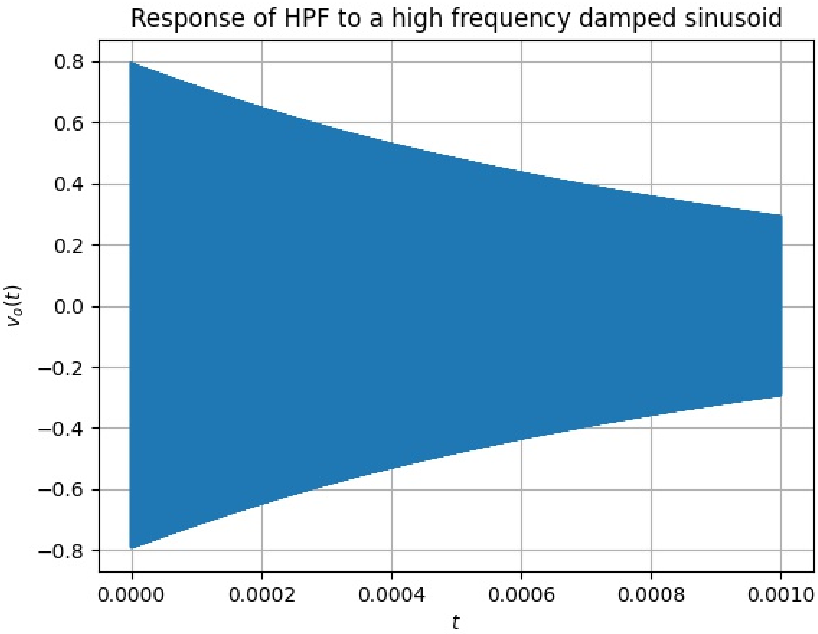

Figure 4: HPF output for $e^{-1000t}cos(2 \times 10^6 \pi t)$

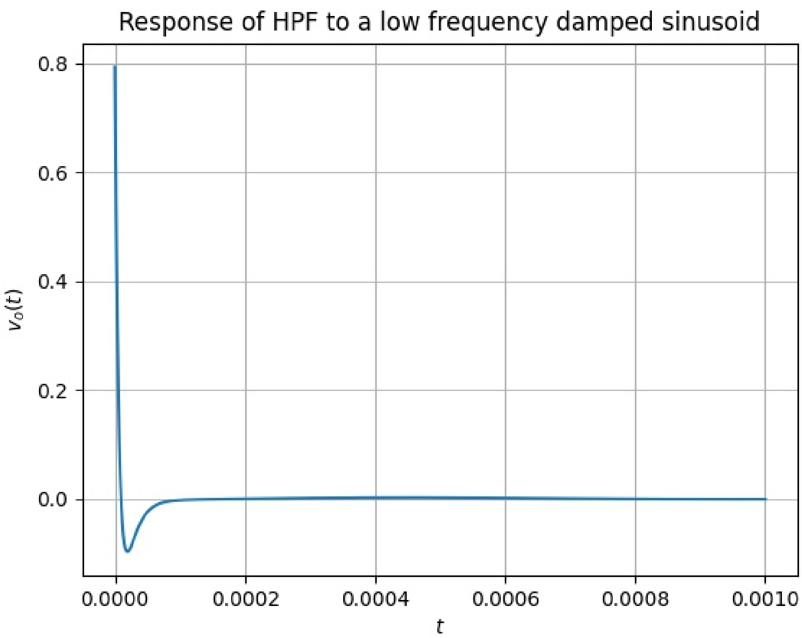

Figure 5: HPF output for $e^{-1000t}cos(2000\pi t)$

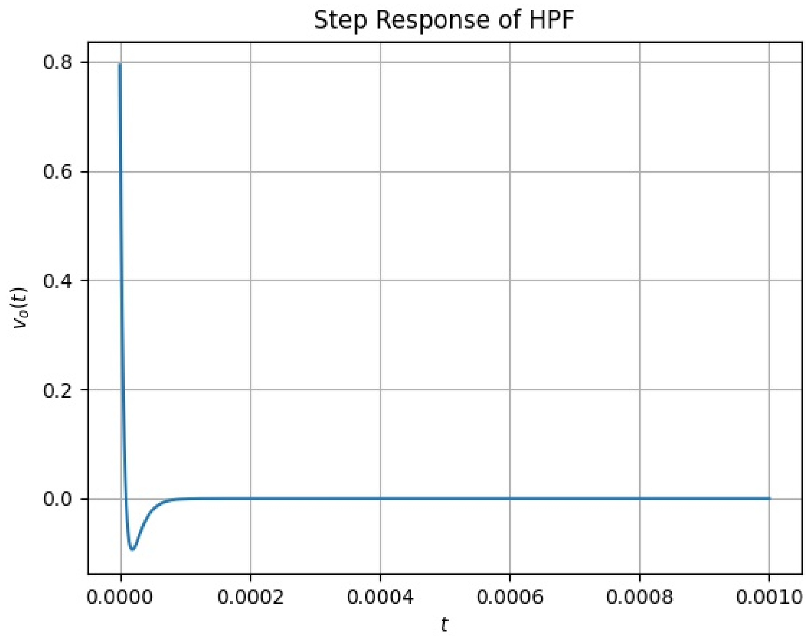

Figure 6: Step Response of Highpass Filter

We see that the high frequency components of $u(t)$ are very small because of the $\frac{1}{j\omega}$ variation. Hence, the output of HPF coverges to 0.

Conclusion

We have simulated two types of filters, lowpass and highpass using sympy and scipy.signal libraries. We have observed the responses of these systems to various input signals.