EE2703: ASSIGNMENT 7

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1 Introduction

The aim of this assignment is to analyse circuits using the Symbolic algebra capabilities of `Sympy`.

Low-Pass Filter

In this section, we analyse the low pass filter circuit of output:

$$V_o(s) = \frac{-0.0001586 \cdot V_i(s)}{2 \times 10^{-14} s^2 + 4.414 \times 10^{-9} s + 0.0002} \tag{1}$$

From (1), we get the step response of the circuit as:

$$V_o(s) = \frac{-0.0001586 \cdot \frac{1}{s}}{2 \times 10^{-14} s^2 + 4.414 \times 10^{-9} s + 0.0002} \tag{2}$$

Now, we can easily create a `signal.lti` object with the coefficients we got, and use `signal.bode` to obtain the magnitude plot, which is shown below.

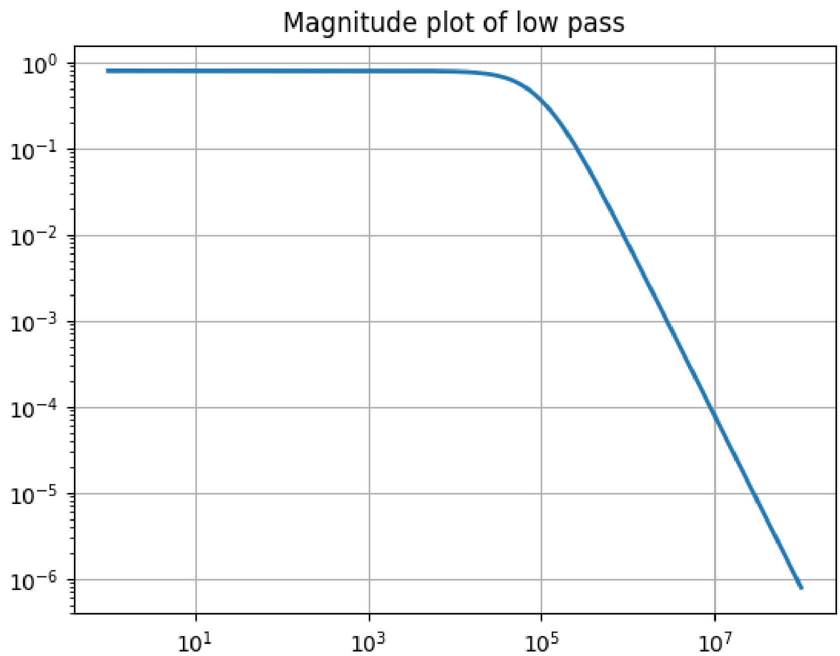

Figure 1: Bode Magnitude of LPF

To see the step response of the system, we can use `signal.step`. The step response of the system is shown below.

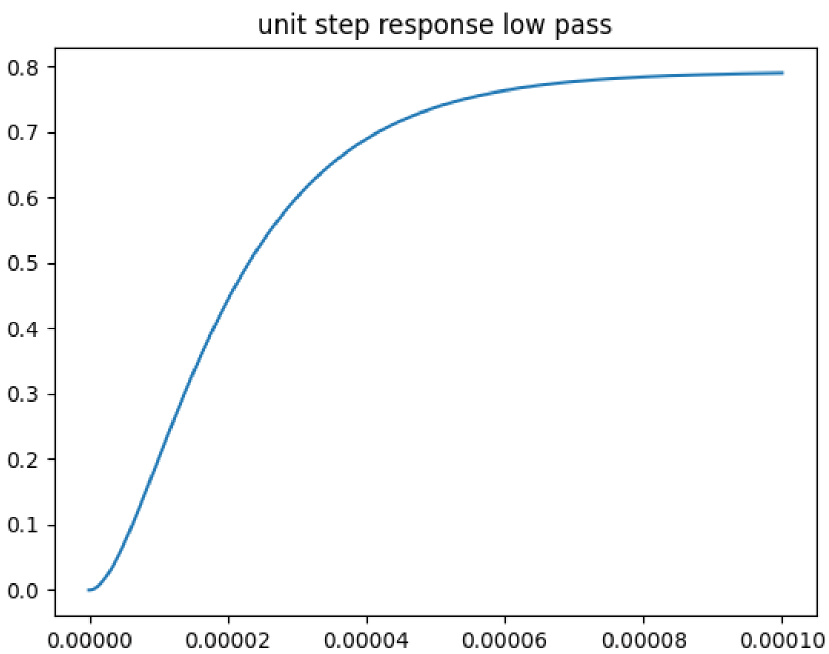

Figure 2: Step response of LPF

2 High-Pass Filter

We shall now look at a slightly modified version of the above circuit.

Code:

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

#Highpass Filter
A,b,V=highpass(10000,10000,1e-9,1e-9,1.586,1)
Vo=V[3]
w=np.logspace(0,8,801)
ss=1j*w
s = sy.symbols('s')
hf=sy.lambdify(s,Vo,'numpy')
v=hf(ss)
plt.loglog(w,abs(v),lw=2)
plt.title(r'Magnitude plot of High pass')
plt.grid(True)
plt.show()
```

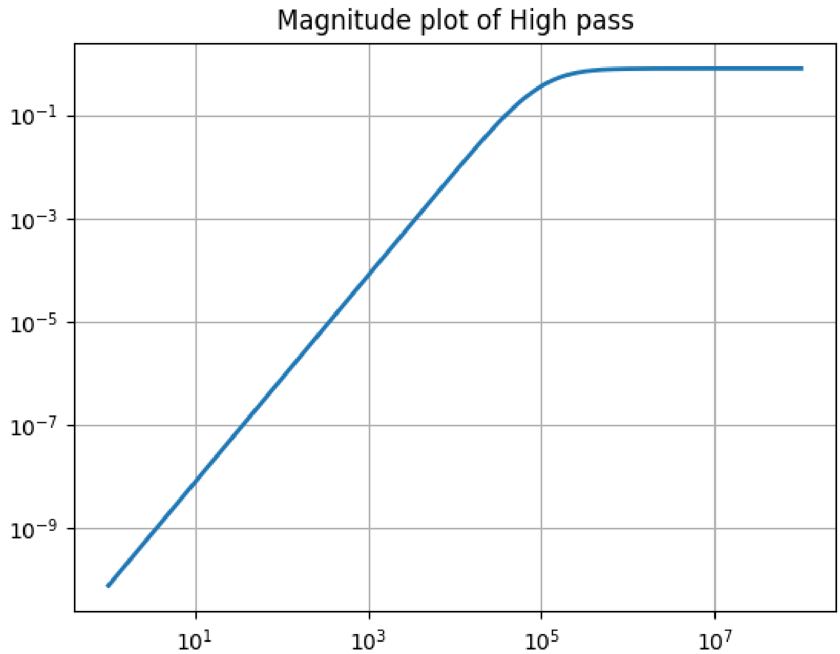

Figure 3: Bode Magnitude plot of HPF

Computing the Sinusoidal Response of Highpass Filter

Code:

```
Vo_signal = convert(Vo)
# computes the sinusoidal response of the highpass
t = \np.linspace(0,6/(1e6),2001)
Si  = np.sin(2000*np.pi*t)+np.cos(2*1e6*np.pi*t)
t,sin_res,svec = sp.lsim(Vo_signal,Si,t)

fig, axes = plt.subplots(1, 2, \figsize=(12, 5), sharey = True)
axes[0].plot(t,sin_res)
axes[0].grid()
axes[0].set_title(' Output of highpass filter to given sinusoidal Input  ')
axes[0].set_xlabel('Time')
axes[0].set_ylabel('y(t)')

axes[1].plot(t,Si)
axes[1].grid()
axes[1].set_title(' Input to highpass filter')
axes[1].set_xlabel('Time')
axes[1].set_ylabel('x(t)')
plt.show()
```

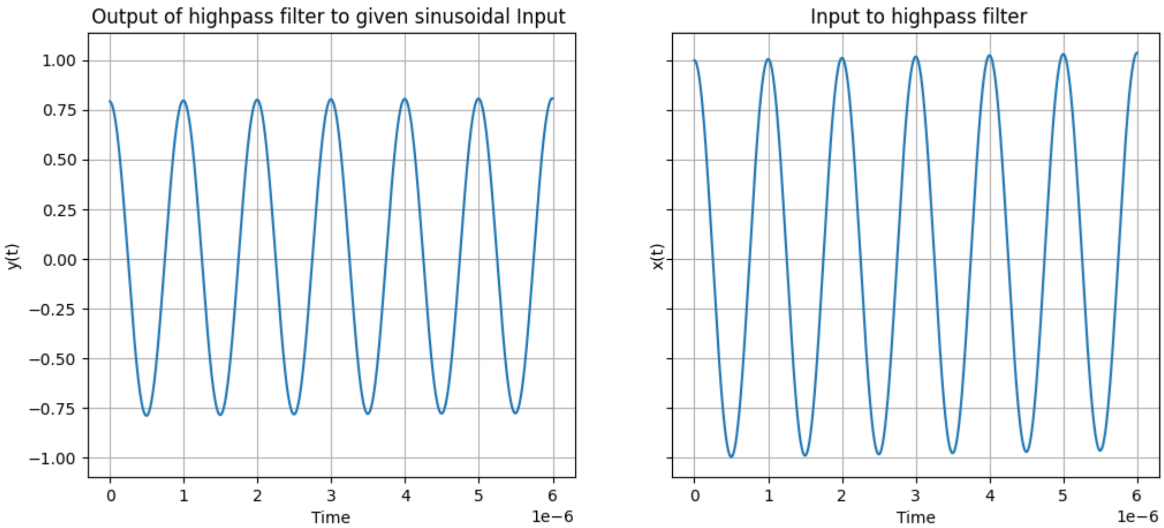

Figure 4: Sinusoidal Response of Highpass Filter

Computing the Damped Sinusoidal Response of Highpass Filter

Code:

```
t = np.linspace(0.0,3e-5,100001)
Di = np.exp(-1e5*t)*np.cos(2*1e6*np.pi*t)
t,sin_res,svec = sp.lsim(Vo_signal,Di,t)

fig, axes = plt.subplots(1, 2, figsize=(12, 5), sharey = True)
axes[0].plot(t,sin_res)
axes[0].grid()
axes[0].set_title('Output of highpass filter to given damping input')
axes[0].set_xlabel('Time')
axes[0].set_ylabel('y(t)')
axes[1].plot(t,Di)
axes[1].grid()
axes[1].set_title('Input to highpass filter')
axes[1].set_xlabel('Time')
axes[1].set_ylabel('x(t)')
plt.show()
```

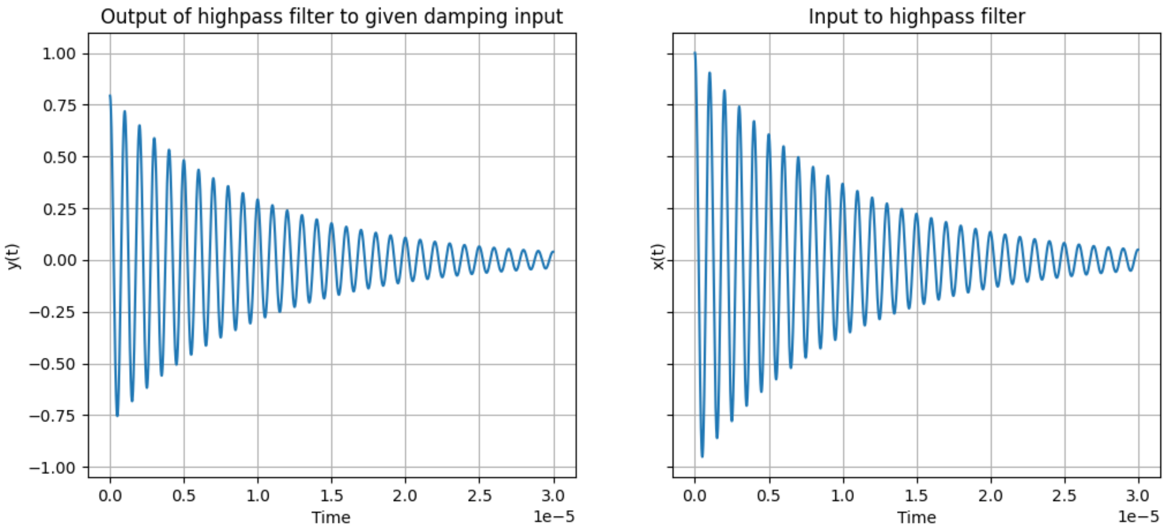

Figure 5: Damped Sinusoidal Response of Highpass Filter

Computing the Step Response of input(1/s)

Code:

```
# The below code computes the unit step response by passing the Vi as 1/s
A,b,V=lowpass(10000,10000,1e-9,1e-9,1.586,1/s)
Vo=V[3]
Vo_signal = convert(Vo)
t,Vo_time = sp.impulse(Vo_signal,None,np.linspace(0,100e-6,20001))
plt.plot(t,Vo_time)
plt.grid()
plt.title('step response of lowpass(1/s)')
plt.plot()
plt.show()

A,b,V=highpass(10000,10000,1e-9,1e-9,1.586,1/s)
Vo=V[3]
Vo_signal = convert(Vo)
t,Vo_time = sp.impulse(Vo_signal,None,np.linspace(0,100e-6,20001))
plt.plot(t,Vo_time)
plt.grid()
plt.title('step response of Highpass(1/s)')
plt.plot()
plt.show()
```

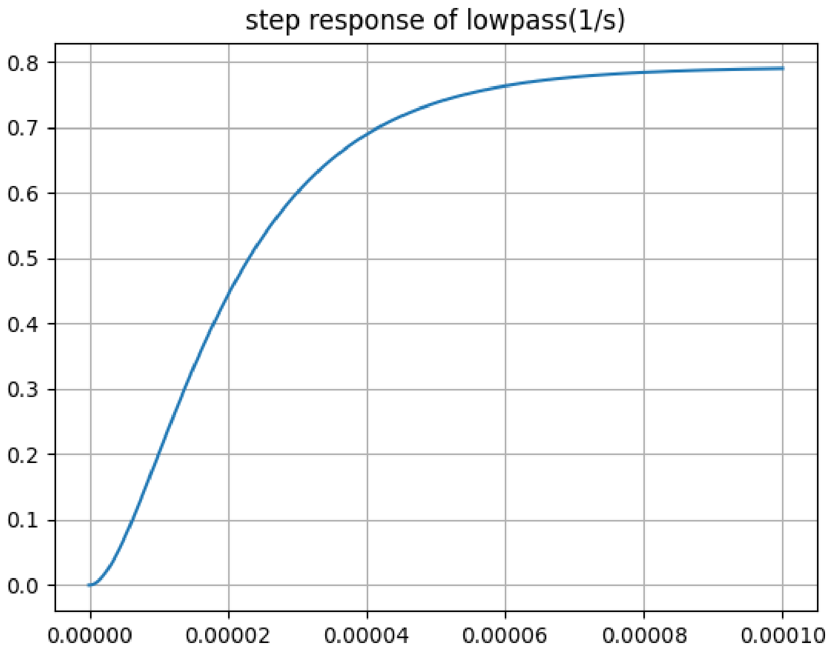

Figure 6: Step Response of LPF

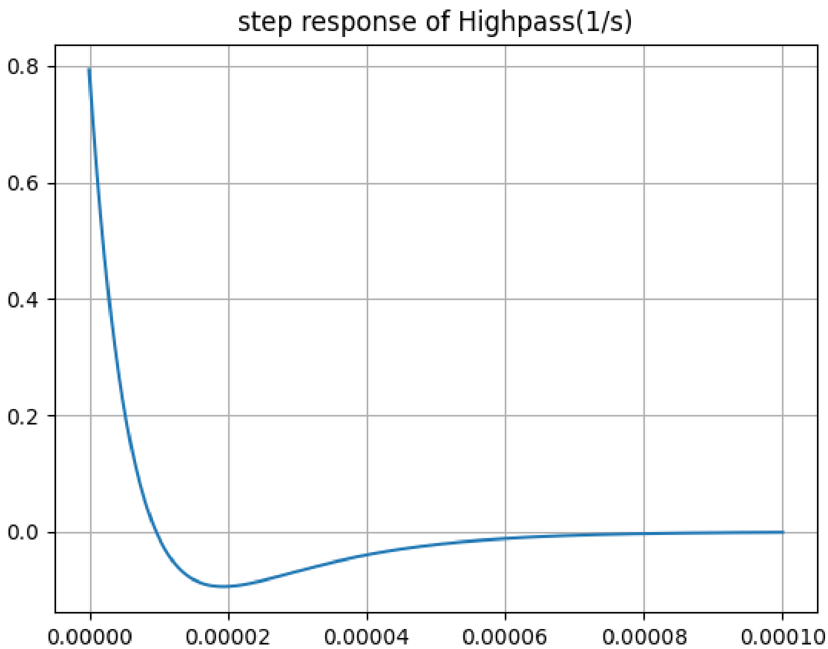

Figure 7: Step Response of HPF

3 Conclusion

`Sympy` provides a convenient way to analyse LTI systems using their Laplace transforms. The toolbox was used to study the behaviour of a low pass filter,implemented using an op-amp of gain G. For a mixed frequency sinusoid as input, it was found that the filter suppressed the high frequencies while allowing the low frequency components. Similarly, a high pass filter was implemented using an op-amp with the same gain. The magnitude response of the filter was plotted and its output was analysed for damped sinusoids.The step response of the filter was found to have a non-zero peak at $t = 0$,due to the sudden change in the input voltage.