Circiut Analysis using Sympy

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1 Introduction

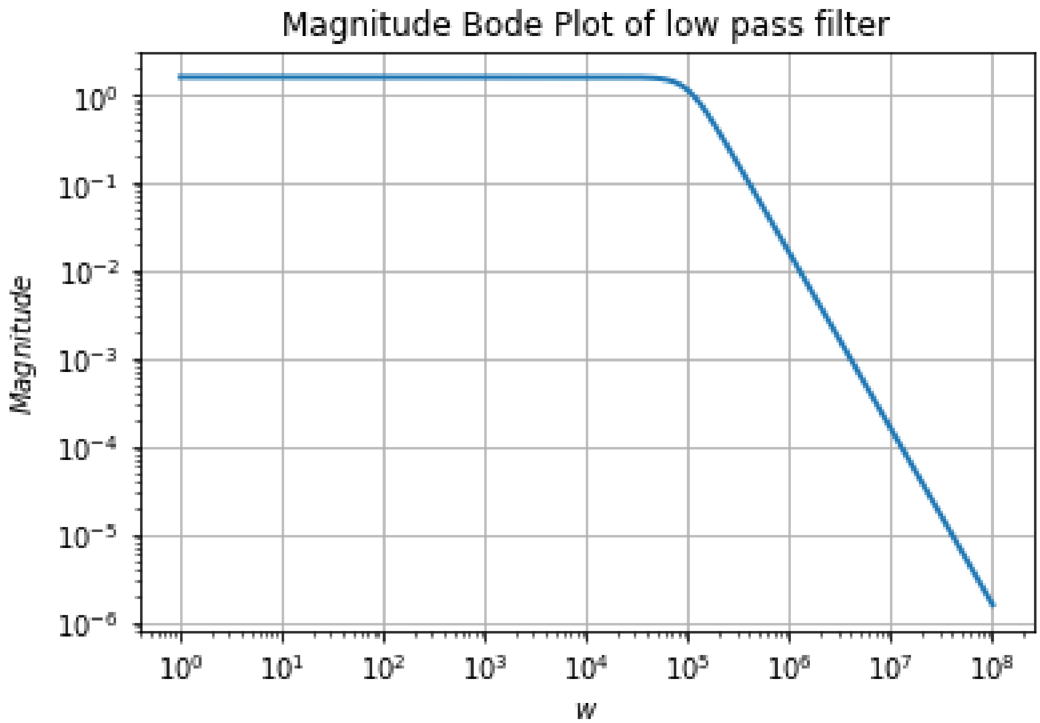
Let us import what all modules we need.

```
In [14]: from sympy import *
         import numpy as np
         import matplotlib.pyplot as plt
         import scipy.signal as sp
```

```
In [27]: def lowpass(R1,R2,C1,C2,G,Vi):
             s=symbols('s')
             A=Matrix([[0,0,1,-1/G],[-1/(1+s*R2*C2),1,0,0],[0,-1000,1000,1],[-1/R1-1/R2-s*C1,1/R
             b=Matrix([0,0,0,-Vi/R1])
             V=A.inv()*b
             return A,b,V
```

```
In [28]: A,b,V=lowpass(10000,10000,1e-9,1e-9,1.586,1)
         print('G=1000')
         Vo=V[3]
         Vo=simplify(Vo)
         print(Vo)
         w=np.logspace(0,8,801)
         ss=1j*w
         s=symbols('s')
         hf=lambdify(s,Vo,'numpy')
         v=hf(ss)
         plt.loglog(w,abs(v),lw=2)
         plt.xlabel("$w$")
         plt.ylabel("$Magnitude$")
         plt.title("Magnitude Bode Plot of low pass filter")
         plt.grid(True)
         plt.show()
```

```
0.1/(6.31517023959647e-12*s**2 + 8.94551071878941e-7*s + 0.0631517023959647)
```

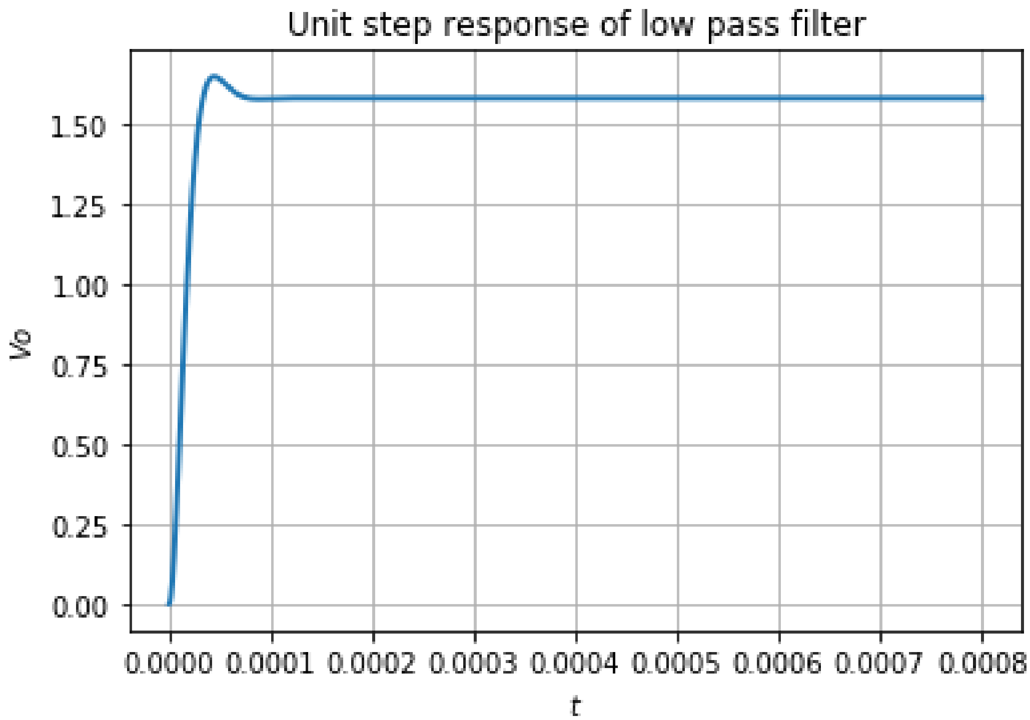


2 Questions in Assignment

2.1 Question 1

To obtain the step response of the circuit, we multiply the transfer function with 1/s in the laplace domain and then convert it to the time domain using scipy.signal impulse method.

```
In [29]: H=Vo*1/s
         num_s,den_s=(np.array(Poly(thing,s).all_coeffs(),dtype=float) for thing in fraction(H))
         tt=np.linspace(0,0.0008,1000)
         t,x=sp.impulse(sp.lti(num_s,den_s),None,tt)
         plt.plot(t,x,lw=2)
         plt.grid(True)
         plt.xlabel('$t$')
         plt.ylabel('$Vo$')
         plt.title("Unit step response of low pass filter")
         plt.show()
```



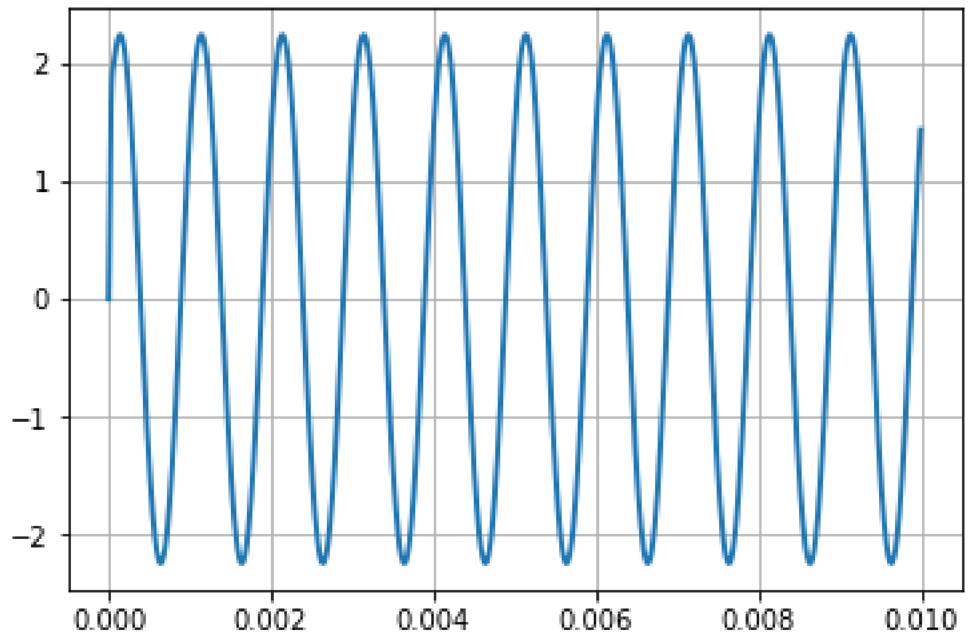
2.2 Question 2

Here, the input is

$$(sin(2000\pi t) + cos(2 * 10^6 \pi t))u(t)$$

We need to determine the output voltage $v_0(t)$. We can calculate it by convoluting the transfer function with input voltage using sp.lsim

```
In [30]: num_s,den_s=(np.array(Poly(thing,s).all_coeffs(),dtype=float) for thing in fraction(Vo)
         tt=np.linspace(0,0.01,1000)
         Vi=np.sin(2000*np.pi*tt)+np.cos(2000000*np.pi*tt)
         t,x,svec=sp.lsim(sp.lti(num_s,den_s),Vi,tt)
         plt.plot(t,x,lw=2)
         plt.grid(True)
         plt.show()
```



Because it is a low pass filter, we can say that high frequency cosine term is attenuated and low frequency sine term is not.

2.3 Question 3

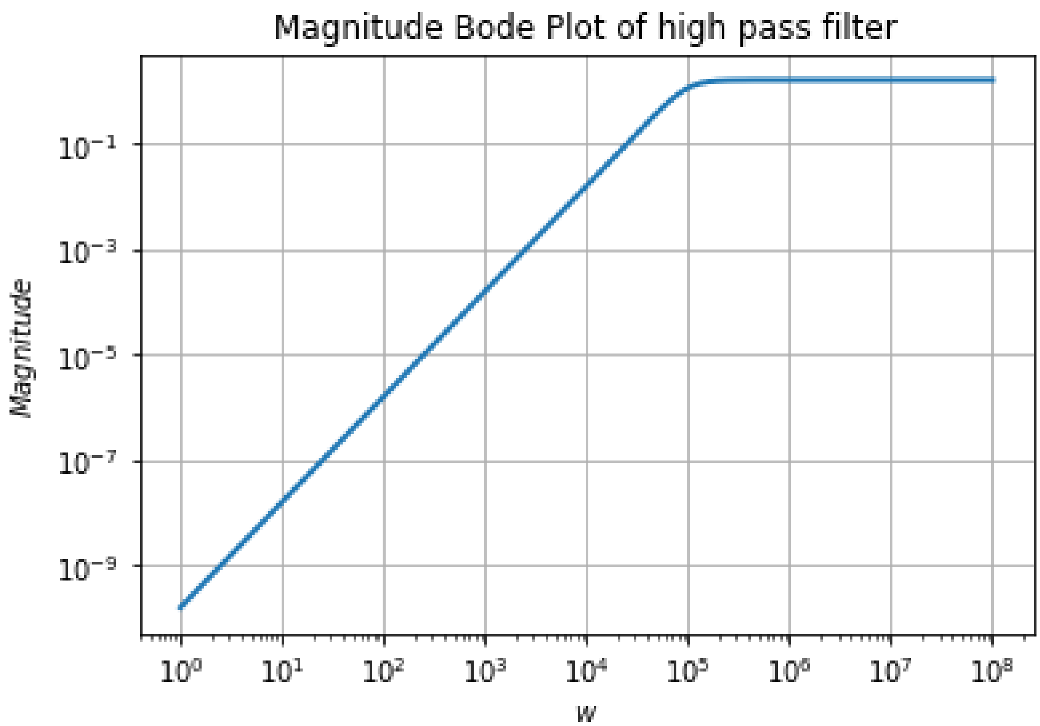
Let us write the nodal equations and form a matrix from which all the unknown voltages can be found.

```
In [32]: def highpass(C1,C2,R1,R3,G,Vi):
             s=symbols('s')
             A=Matrix([[0,0,1,-1/G],[(-s*C2*R3)/(1+s*R3*C2),1,0,0],[0,-1000,1000,1],[-s*C1-s*C2-
             b=Matrix([0,0,0,-Vi*s*C1])
             V=A.inv()*b
             return A,b,V
```

```
In [33]: A,b,V=highpass(1e-9,1e-9,10000,10000,1.586,1)
         s=symbols('s')
         Vo=V[3]
         print(simplify(Vo))
         Vo=simplify(Vo)
         w=np.logspace(0,8,801)
         ss=1j*w
         hf=lambdify(s,Vo,'numpy')
         v=hf(ss)
         plt.loglog(w,abs(v),lw=2)
         plt.xlabel("$w$")
         plt.ylabel("$Magnitude$")
```

```
plt.title("Magnitude Bode Plot of high pass filter")
plt.grid(True)
plt.show()
```

```
1.0e-11*s**2/(6.31517023959647e-12*s**2 + 8.94551071878941e-7*s + 0.0631517023959647)
```



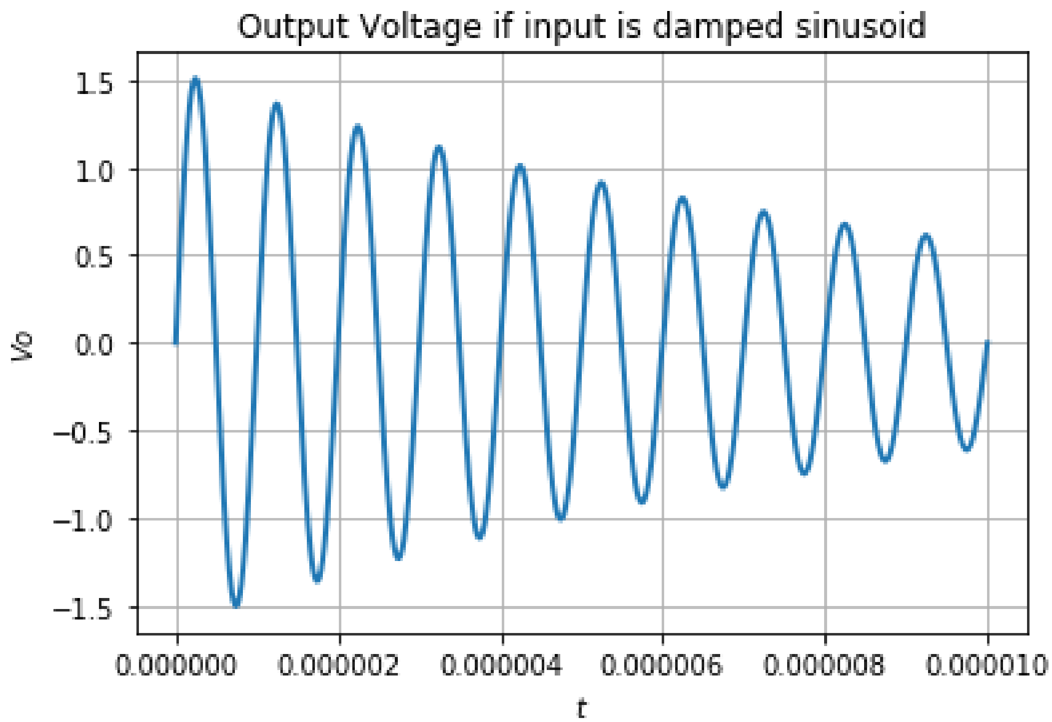
We can see that low frequency terms are getting attenuated and only high frequency terms are not.

2.4 Question 4

Same as Question 2, we can find the output of damped sinusoid by using sp.lsim (Convolution in time domain)

```
In [34]: num_s,den_s=(np.array(Poly(thing,s).all_coeffs(),dtype=float) for thing in fraction(Vo)
         print(num_s,den_s)
         tt=np.linspace(0,0.00001,1000)
         Vi=np.exp(-100000*tt)*np.sin(2*10**6*np.pi*tt)
         t,x,svec=sp.lsim(sp.lti(num_s,den_s),Vi,tt)
         plt.plot(t,x,lw=2)
         plt.grid(True)
         plt.xlabel('$t$')
         plt.ylabel('$Vo$')
         plt.title("Output Voltage if input is damped sinusoid")
         plt.show()
```

```
num_s=[1.e-11 0.e+00 0.e+00]
den_s=[6.31517024e-12 8.94551072e-07 6.31517024e-02]
```



2.5 Question 5

As mentioned in the question, let us set the Vi value as 1/s, which signifies input is a step function. After using sp.impulse on the Vo(s), we get the time-domain step response.

```
In [35]: s=symbols('s')
         A,b,V=highpass(1e-9,1e-9,10000,10000,1.586,1/s)
         Vo=V[3]
         print(simplify(Vo))
         Vo=simplify(Vo)
```

```
1.0e-11*s/(6.31517023959647e-12*s**2 + 8.94551071878941e-7*s + 0.0631517023959647)
```

```
In [36]: num_s,den_s=(np.array(Poly(thing,s).all_coeffs(),dtype=float) for thing in fraction(Vo)
         tt=np.linspace(0,0.001,8001)
         t,x=sp.impulse(sp.lti(num_s,den_s),None,tt)
         plt.plot(t,x,lw=2)
         plt.grid(True)
         plt.xlabel('$t$')
```

```
plt.ylabel('$Vo$')
plt.title("Unit step response of high pass filter")
plt.show()
```