

PSDE5009 Assignment 1

by Christopher Milner

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Title:

Analysis, Simulation and Evaluation of Electrical Circuits and Electronic Systems

Course:

HNC Electrical and Electronic Engineering

Module:

PSDE5009 Electrical Principles, Methods and Simulation

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1.Introduction

2. Analysis of First Order Electric Circuits

In this part of the assignment a series circuit with 0.1H inductor and 25Ω resistor will be analysed using a La Place model

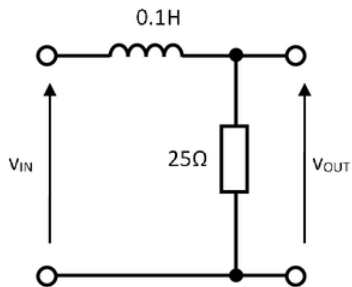


Figure 1: Low Pass Filter

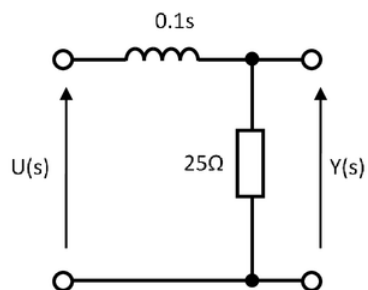


Figure 2: La Place Model

0.1H 25Ω

$$\tau = \frac{L}{R}$$

$$\tau = \frac{0.1}{25} = 0.004$$

$$H(s) = \frac{R}{sL + R}$$

$$H(s) = \frac{25}{0.1s + 25} = \frac{1}{0.004s + 1}$$

or

$$H(s) = \frac{1}{\tau s + 1}$$

$$H(s) = \frac{25}{0.1s + 25} = \frac{1}{0.004s + 1}$$

```

num=[1];
den=[0.004 1];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid

```

Figure 3 Matlab program

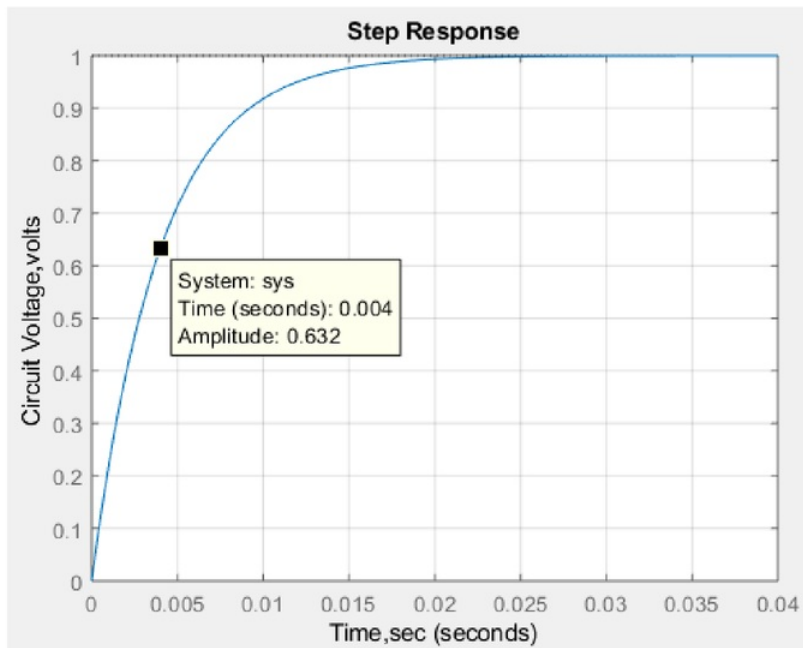


Figure 4 High pass filter plot

$$Y(s) = \frac{R}{sL + R} U(s)$$

$$\frac{Y(s)}{U(s)} = \frac{25}{s0.1 + 25}$$

$$\omega c = \frac{25}{0.1} = 250$$

$$H(s) = \frac{250}{s + 250}$$

```

1 %Low Pass Frequency Response|
2 - num=[250];
3 - den=[1 250];
4 - bode(num,den);
5 - xlabel('Time,sec');
6 - ylabel('Circuit Voltage,volts');
7 - grid

```

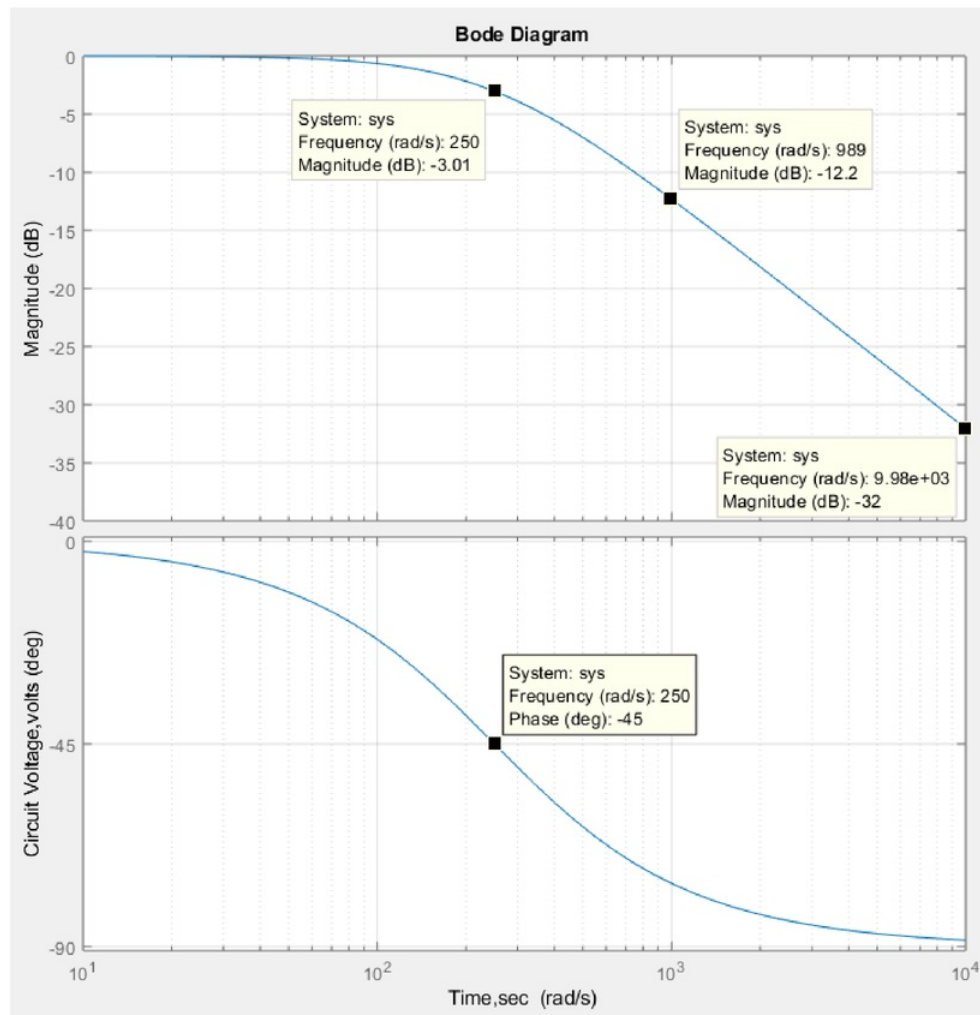


Figure 5

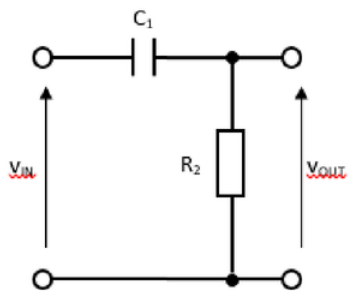


Figure 6: High Pass Filter

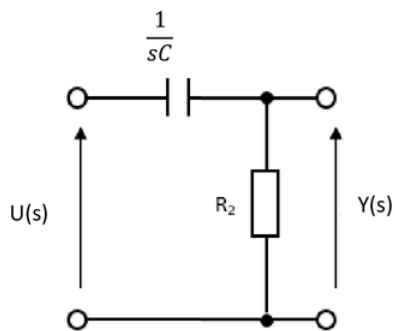


Figure 7: La Place Model

$$H(s) = \frac{\tau s}{(\tau s + 1)}$$

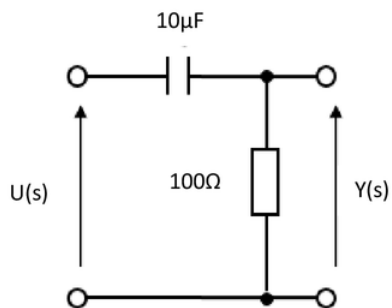


Figure 8

$$\tau = 100 \times 10 \times 10^{-6}$$

$$\tau = 0.001s$$

$$H(s) = \frac{0.001}{0.001 + 1}$$

```

1 %High pass time constant
2 num=[0.00099 0];
3 den=[0.00099 1];
4 step(num,den);
5 xlabel('Time,sec');
6 ylabel('Circuit Voltage,volts');
7 grid

```

Figure 9

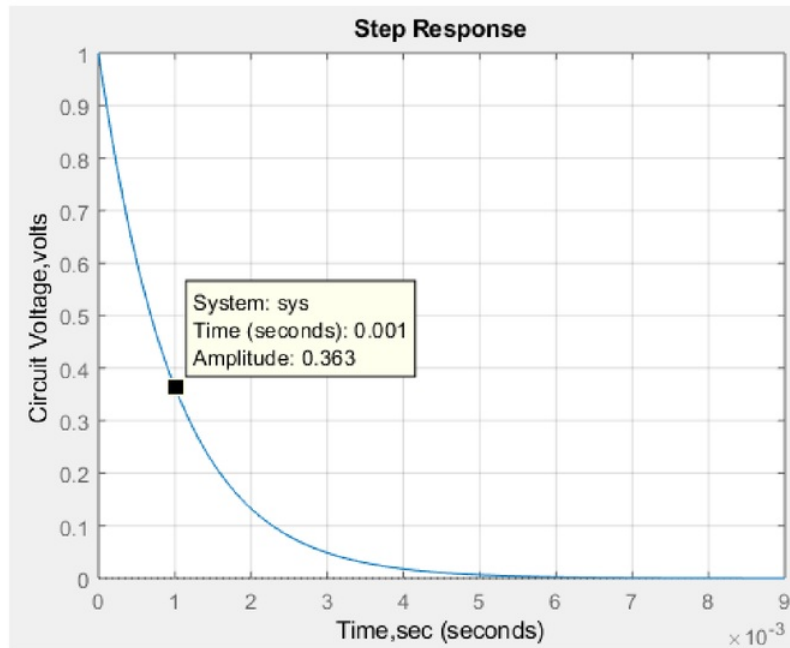


Figure 10

$$\omega c = \frac{1}{RC} = \frac{1}{100 \times 10 \times 10^{-6}} = 1000$$

$$H(s) = \frac{s}{s + \omega c} = \frac{s}{s + 1000}$$

```

%High Pass Frequency Response
num=[1 0];
den=[1 1000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid

```

Figure 11

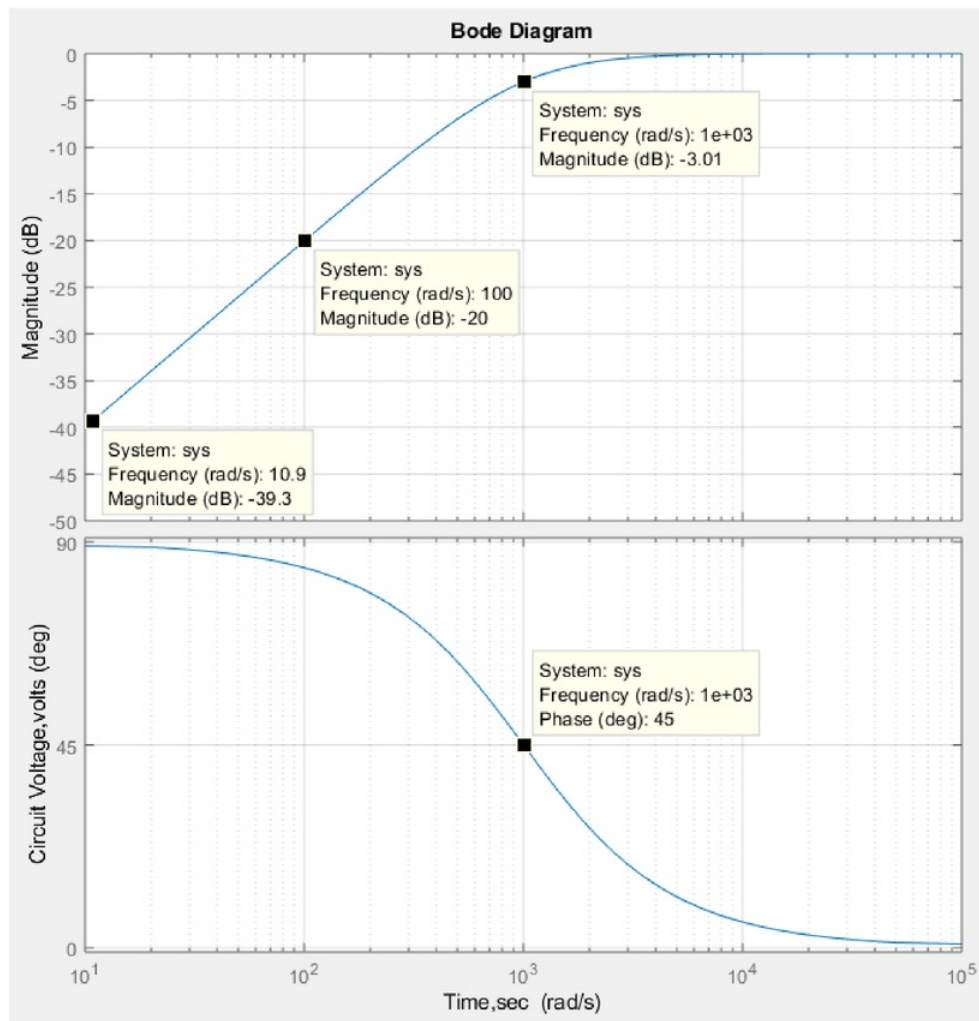


Figure 12

3. Analysis of Second Order Electric Circuits

Low Pass Filter

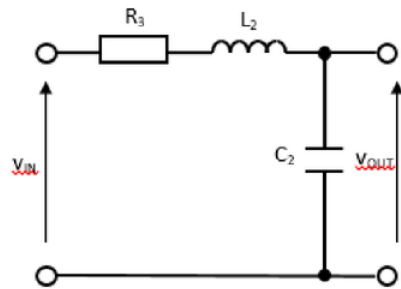


Figure 13: Low Pass Filter

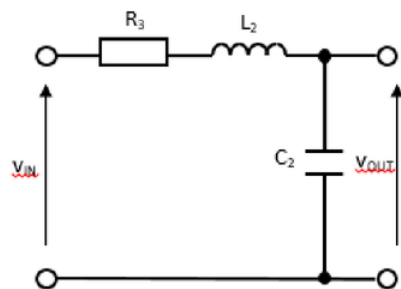


Figure 14

Potential divider rule

$$Y(s) = \frac{\frac{1}{sC}}{R + sL + \frac{1}{sC}} X(s)$$

Multiply by s/L

$$\frac{Y(s)}{X(s)} = \frac{\frac{1}{sC} \times \frac{s}{L}}{R \times \frac{s}{L} + sL \times \frac{s}{L} + \frac{1}{sC} \times \frac{s}{L}}$$

Therefore

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

Standard second order system equation

$$H(s) = \frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

Under Damped

K = gain

ω_n = the natural frequency of oscillation

ζ = the damping factor

$R = 4$

$L = 0.2$

$C = 50\mu\text{F}$

$$H(s) = \frac{100000}{s^2 + 20s + 100000}$$

Passive system so $K = 1$

$$\omega_n^2 = \frac{1}{LC} \quad \therefore \quad \omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2 \times 50 \times 10^{-6}}} = 316.22 \text{ rad/s}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{4}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0.032$$

if $\zeta < 1$ the circuit is under damped.

```
%Low Pass RLC
%4 ohm resistor
num=[0 100000];
den=[1 20 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 15

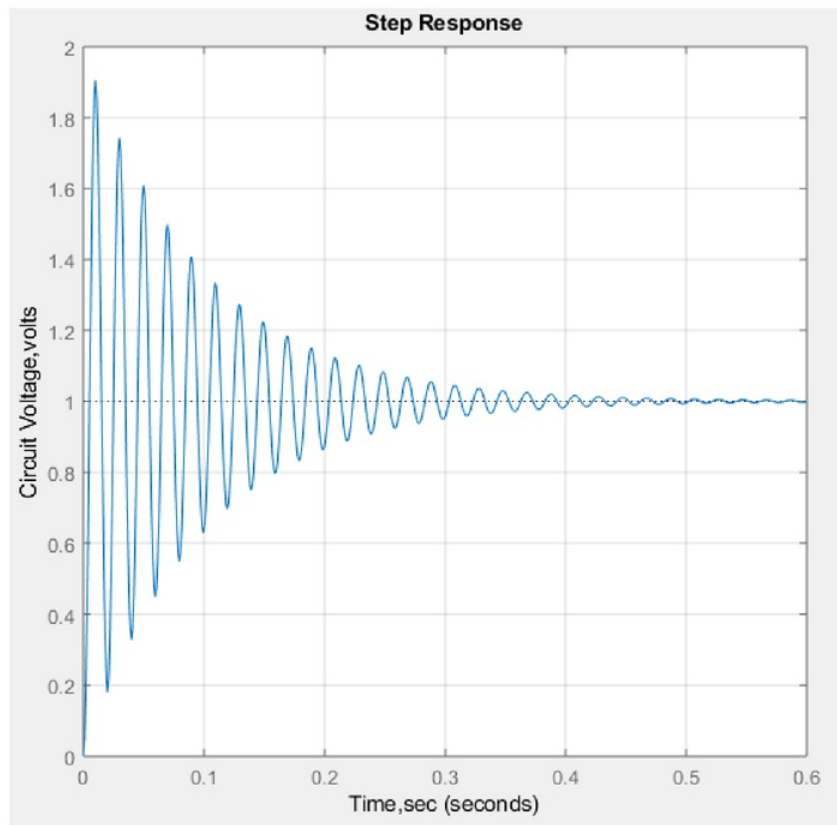


Figure 16

Over Damped

Changing the resistor value to 1k

$$H(s) = \frac{100000}{s^2 + 5000s + 100000}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{1000}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 7.9$$

if $\zeta > 1$ then the circuit is over damped.

```
%Low Pass RLC
%1k ohm resistor
num=[0 100000];
den=[1 5000 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

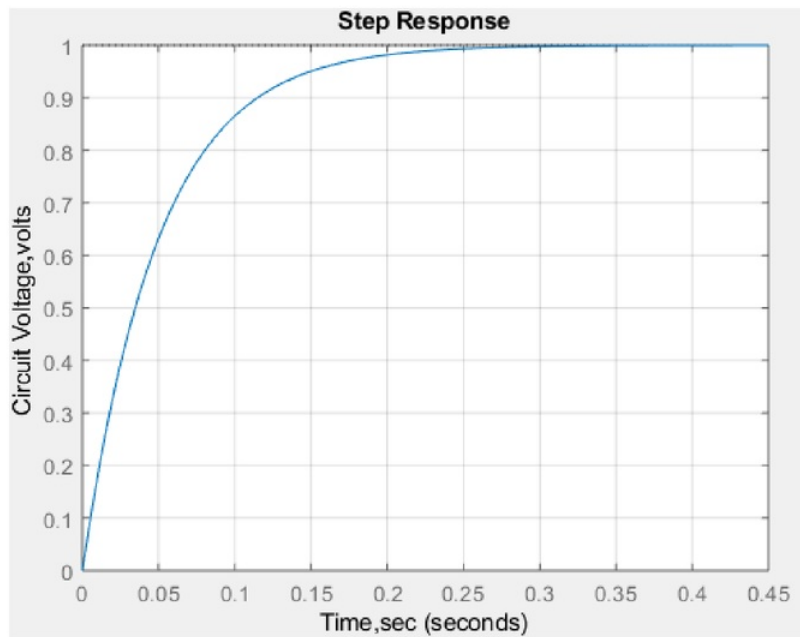


Figure 17

Critically Damped

To have a critically damped circuit the value of ζ must be 1.

To find the value of R when $\zeta = 1$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{R}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = \frac{R}{2} 0.01581$$

$$\frac{1}{0.01581} 2 = R = 126.5 \Omega$$

So

$$H(s) = \frac{100000}{s^2 + 632.5s + 100000}$$

```
%Low Pass RLC
%126.5 ohm resistor
num=[0 100000];
den=[1 632.5 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 18

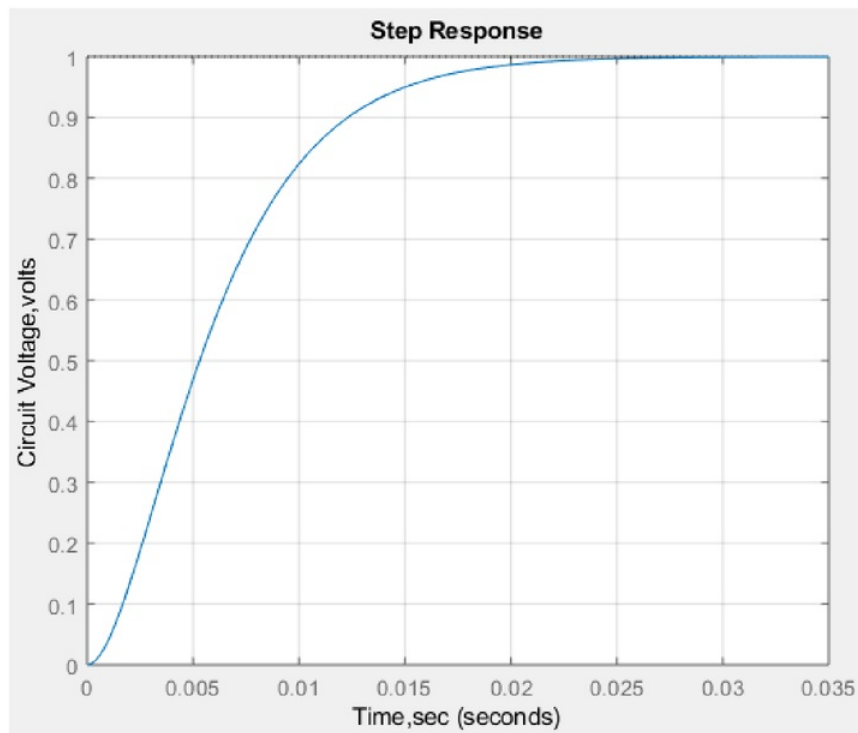


Figure 19

No Damping

And to show the effect of no damping, the resistance is set to zero.

$$H(s) = \frac{100000}{s^2 + 0s + 100000}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{0}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0$$

```
%Low Pass RLC
%0 ohm resistor
num=[0 100000];
den=[1 0 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 20

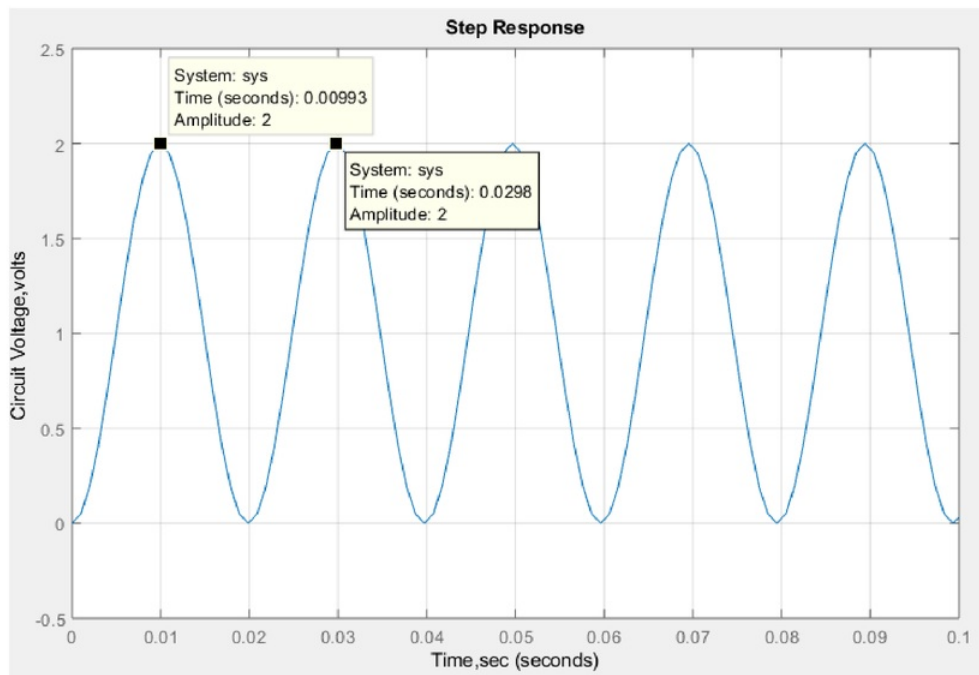


Figure 21

Frequency response

$$Q \text{ Factor} = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{4} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 252.98$$

$$\frac{1}{1000} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 0.253$$

$$\frac{1}{126.5} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 1.2$$

Q factor for a circuit with no resistance is infinity.

```

%Low Pass RLC Frequency Responses
%4 ohm resistor
num=[0 100000];
den=[1 632.5 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
hold
%1K ohm resistor
num=[0 100000];
den=[1 5000 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
%126.5 ohm resistor
num=[0 100000];
den=[1 20 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
%0 ohm resistor
num=[0 100000];
den=[1 0 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid

```

Figure 22

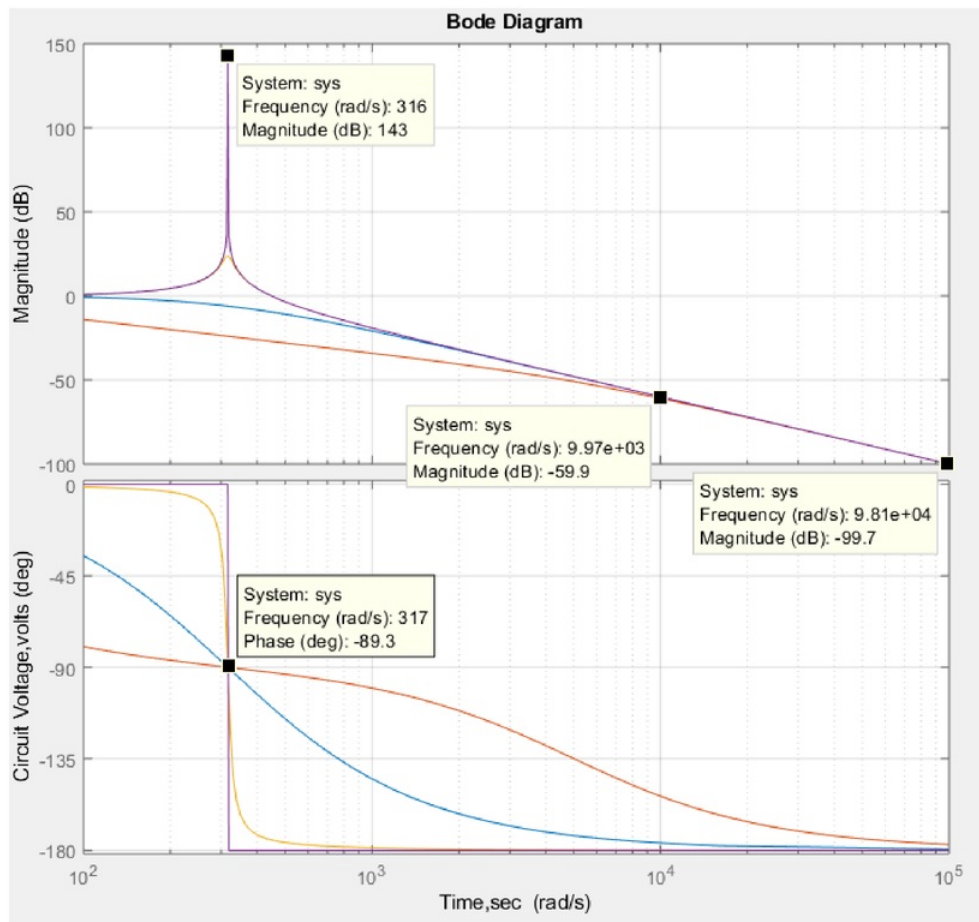


Figure 23

Parallel Resonant Filter

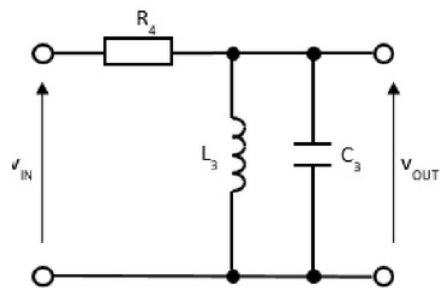


Figure 24: Parallel Resonant Filter

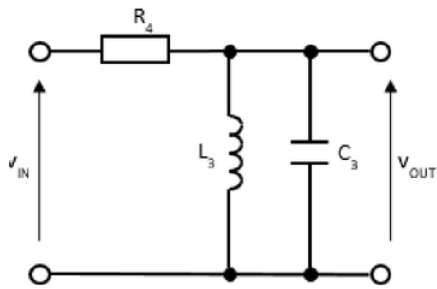


Figure 25

Using the potential divider rule

$$Y(s) = \frac{Zp(s)}{R + Zp(s)} \times X(s)$$

$Zp(s)$ is the parallel impedance of sL and $1/sC$

$$R = 4$$

$$L = 0.2$$

$$C = 50\mu\text{F}$$

The transfer function for this will be

$$H(s) = \frac{s \times 1/RC}{s^2 + 1/RC s + 1/LC}$$

$$1/RC = 5000$$

$$1/LC = 100000$$

$$\therefore H(s) = \frac{5000s}{s^2 + 5000s + 100000}$$

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{8} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 7.906$$

Circuit is overdamped

```
%Parallel Resonant Step Response
%4 ohm resistor
num=[5000 1];
den=[1 5000 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 26

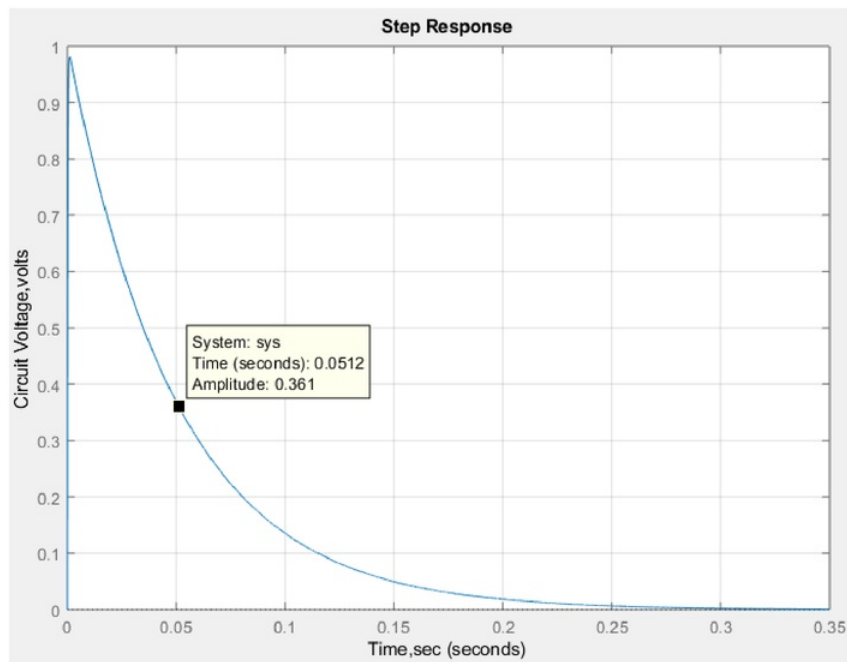


Figure 27

50 ohm resistor

$$1/RC = 400$$

$$1/LC = 100000$$

$$\therefore H(s) = \frac{400s}{s^2 + 400s + 100000}$$

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{100} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 0.632$$

Circuit is underdamped

```
%Parallel Resonant Step Response
%50 ohm resistor
num=[400 1];
den=[1 400 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 28

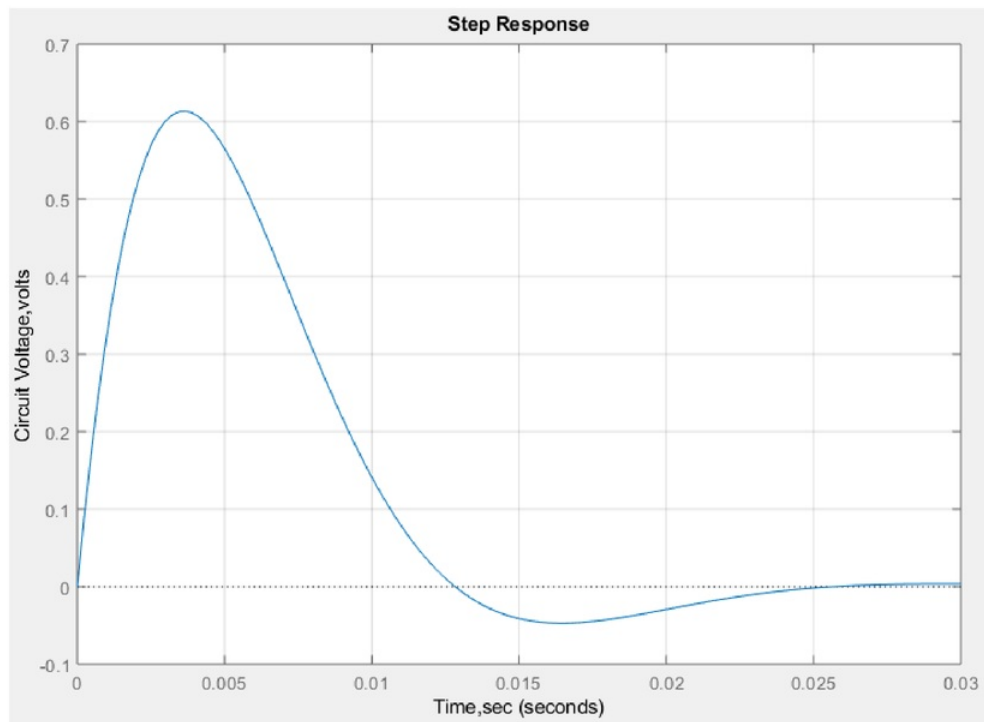


Figure 29

To calculate R when $\zeta = 1$ i.e. critically damped

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2R} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = \frac{1}{2R} 63.245$$

$$R = \frac{63.245}{2} = 31.6$$

$$1/RC = 632.9$$

$$1/LC = 100000$$

$$Hs = \frac{632.9s}{s^2 + 632.9s + 100000}$$

```
%Parallel Resonant Step Response
%63.24 ohm resistor
num=[632.9 1];
den=[1 632.9 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 30

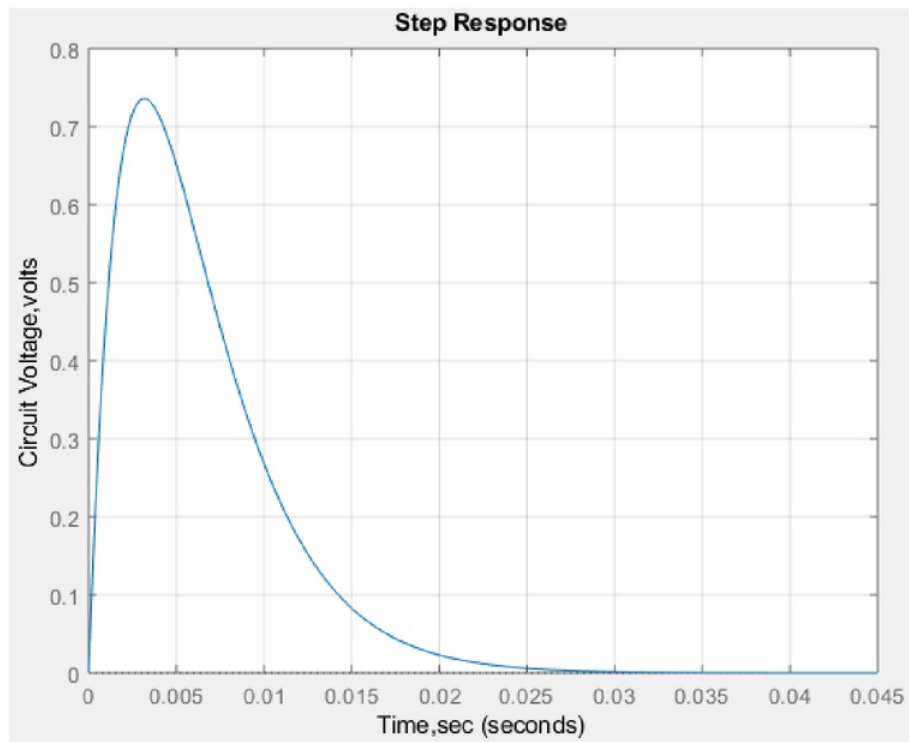


Figure 31

With zero resistance and therefore zero damping.

$$Hs = \frac{0s}{s^2 + 0s + 100000}$$

```
%Parallel Resonant Step Response
%63.24 ohm resistor
num=[0 1];
den=[1 0 100000];
step(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 32

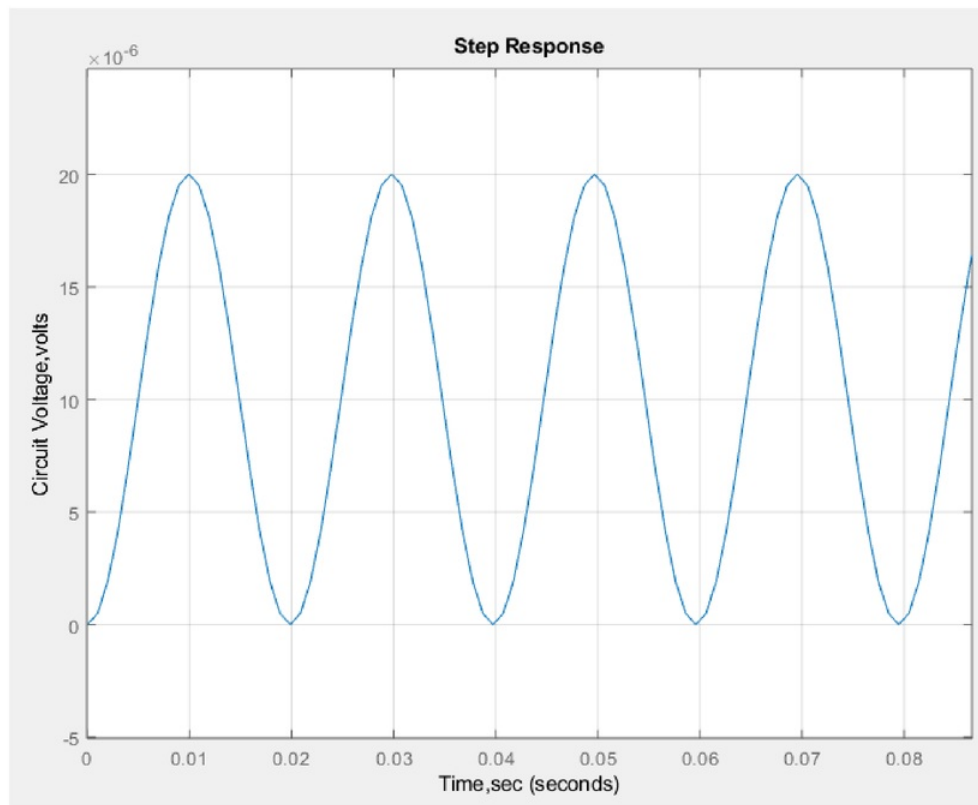


Figure 33

$$\omega_0^2 = 100000$$

$$\omega_0 = 316.23$$

$$\beta = 5000$$

$$Q = 0.063$$

```

%Parallel Resonant Frequency Response
%4 ohm resistor
num=[5000 1];
den=[1 5000 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
hold
%50 ohm resistor
num=[400 1];
den=[1 400 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
%63.24 ohm resistor
num=[632.9 1];
den=[1 632.9 100000];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid

```

Figure 34

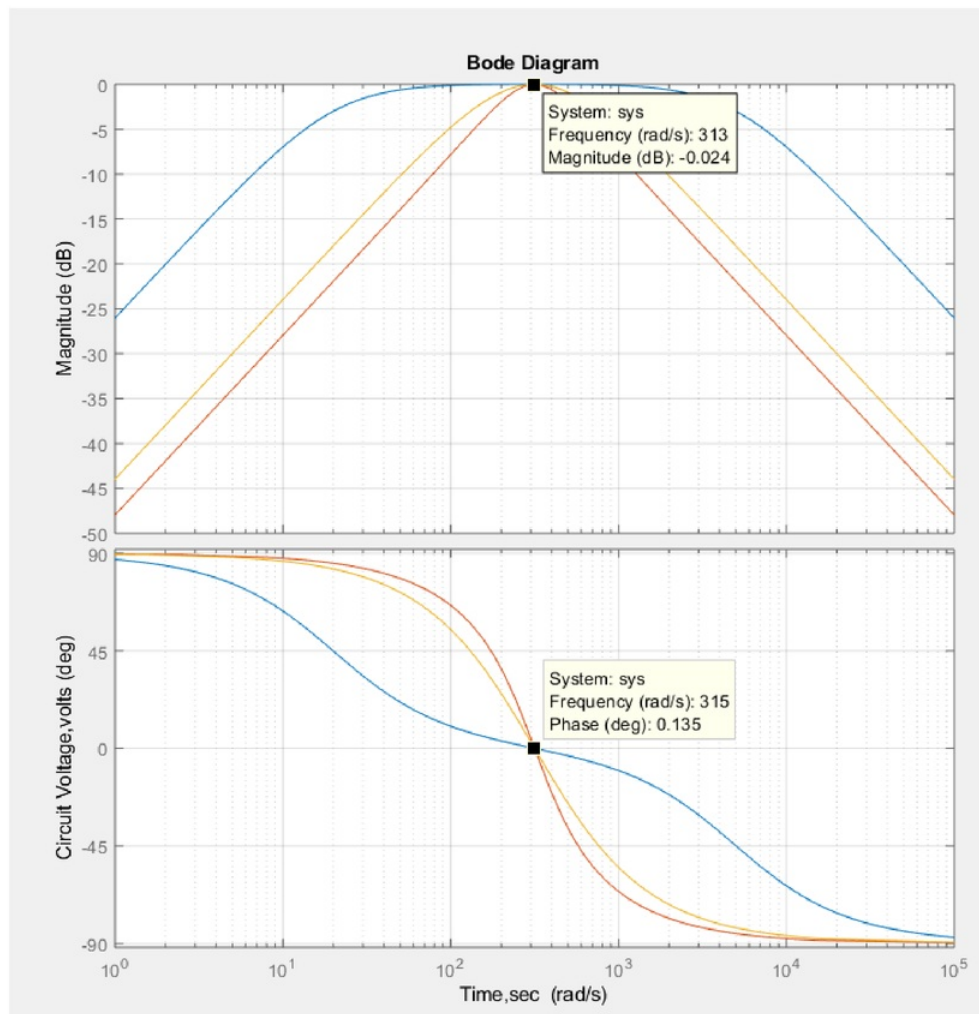


Figure 35

4. Analysis of First Order Electronic Systems

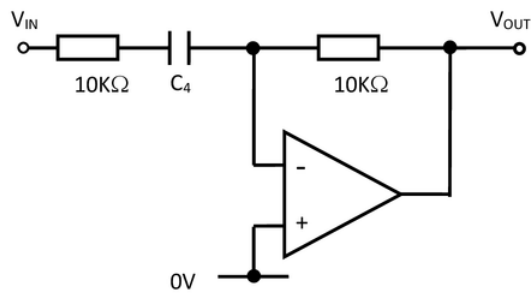


Figure 36

For this task the capacitor C₄ will be 50μF selected as an appropriate value.

Transfer function

$$H(s) = -K \left(\frac{s}{s + \omega C} \right)$$
$$K = \frac{10k}{10k} = 1$$
$$\omega C = \frac{1}{50 \times 10^{-6} \times 10 \times 10^3} = 2$$
$$\therefore H(s) = -1 \left(\frac{s}{s + 2} \right)$$

```
%First Order Electronic Frequency Response
num=[-1 0];
den=[1 2];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 37

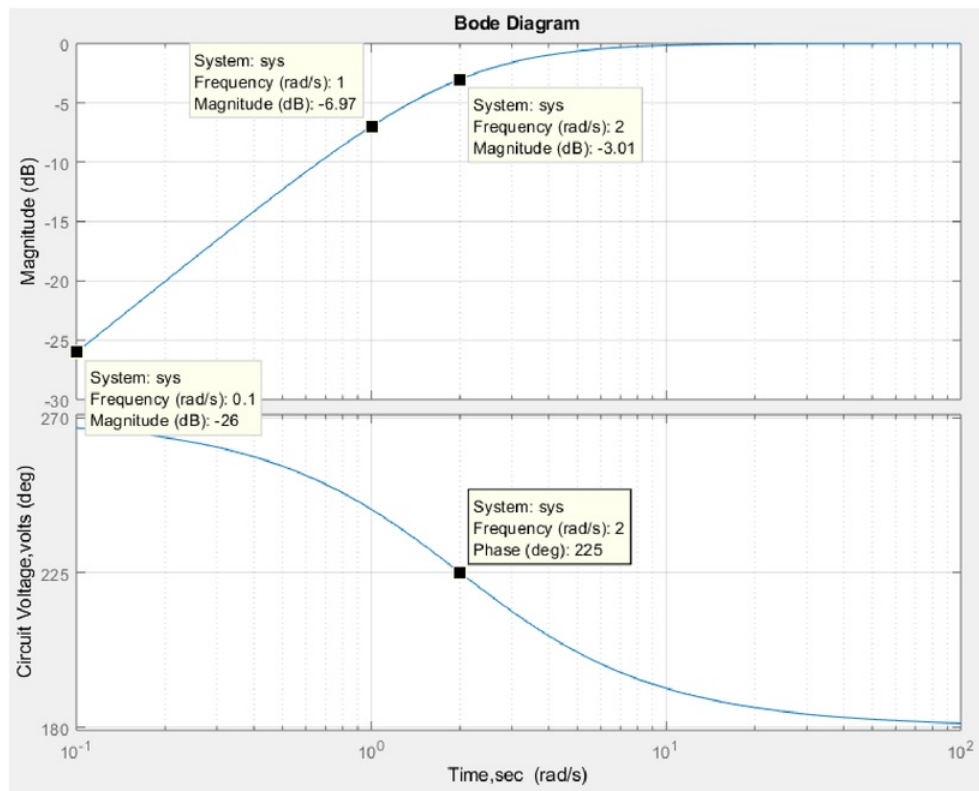


Figure 38

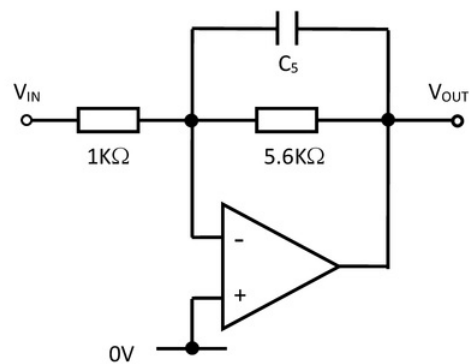


Figure 39

Again, 50uF will be used as a value for C5.

Transfer function

$$H(s) = -K \left(\frac{\omega C}{s + \omega C} \right)$$

$$K = \frac{5600}{1000} = 5.6$$

$$\omega C = \frac{1}{50 \times 10^{-6} \times 5600} = 3.571$$

$$\therefore H(s) = -5.6 \left(\frac{3.571}{s + 3.571} \right)$$

In dB 5.6 =

$$20 \log(5.6) = 14.96$$

$\therefore$ the magnitude at cut off is 11.96

```
%First Order Electronic Frequency Response
num=[-19.9976];
den=[1 3.571];
bode(num,den);
xlabel('Time,sec');
ylabel('Circuit Voltage,volts');
grid
```

Figure 40

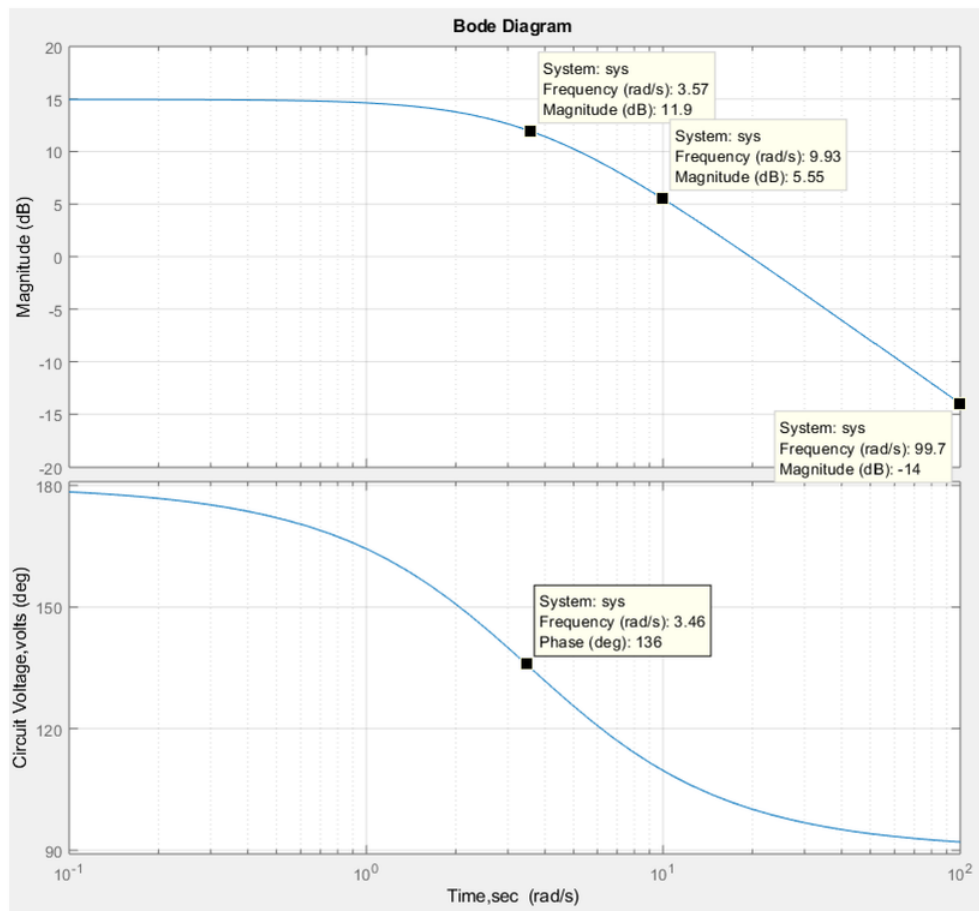


Figure 41

5. Analysis of Second Order Electronic Systems

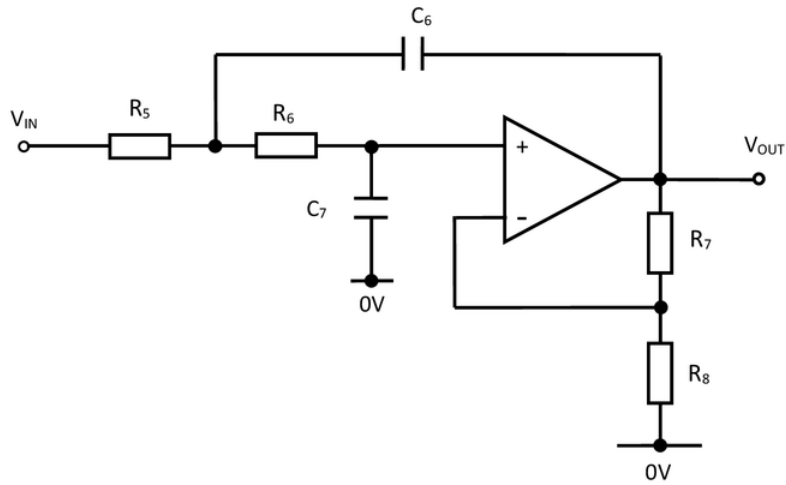


Figure 42

$$\omega C = 500 \text{ rad/s}$$

$$C_6/C_7 = 50 \text{ nF}$$

$$R_5 \& R_6 = \frac{1}{500 \times 50 \times 10^{-9}} = 40 \text{ k}$$

Using Butterworth coefficients $K = 1.586$

$$\therefore \text{if } R_8 = 1 \text{ k} \quad R_7 = (K - 1) \times R_8 = 0.586 \times 1000 = 586 \Omega$$

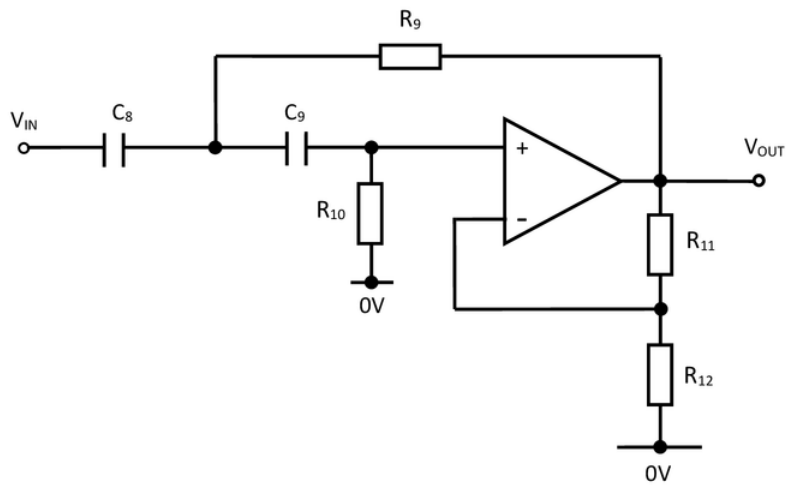


Figure 43

6. Conclusions and Recommendations

In conclusion to this assignment we can see from the theoretical result that the electronic systems are better than electrical systems in terms of maximal linearity and roll off rate, which are the two most important characteristics of a filter circuit.

When simulated using Matlab, the plotted results tended to agree with the theoretical values, proving the theoretical design process to be correct.

PSDE5009 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

48/100

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GRADING FORM: CSG-RUBIC

CHRISTOPHER MILNER

48

RESEARCH-INFORMED LITERATURE



N/A

KNOWLEDGE AND UNDERSTANDING



Sections 2, 3: Explanations for Electric Circuits –
Good diagrams and equations are well presented.
Further marks were available for more explanations
and derivations of all equations and circuits could be
marked up using the Laplace model notation. (5/10)
Sections 4, 5: Explanations for Electronic Systems
– Briefly stated with clear diagrams. (5/10)

10

ANALYSIS

 Sections 2, 3: Analysis, Modelling and Testing of Electric Circuits - Good results with clearly annotated graphs for step and frequency responses. Further marks were available for explanations of results and comparisons with expected values from theory - which is what analysis is all about, you must comments on your results to shown a critical understanding. (8/20) Sections 4, 5: Analysis, Modelling and Testing of Electronic Systems - Good results for task 3 but not present for task 4. Further marks were available for analysis of results, shame you didn't complete tasks 4 and compare roll-offs with task 3. (9/20) Section 6: Conclusions and recommendations – Briefly stated. However, further marks could have been awarded if evidence had been presented in the analysis. No recommendations given. (2/10)

19

PRACTICAL APPLICATION AND DEP.

 Sections 2,3,4,5: Use of Matlab – Generally, good use of Matlab with program clearly presented. (8/10) Sections 2,3,4,5: Accuracy and Presentation Quality of Results – Generally accurate and well presented. (8/10)

16

SKILLS FOR PROFESSIONAL PRAC.

 Section 1: Introduction: None offered. (0/5) All sections: Overall Report Quality - Generally good, figures were numbered and listed. However, further marks were available for numbering pages and more explanations to back up equations. (3/5)

3