

PSDE 5009

by Phillip Rowe

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Electrical and electronic engineering
PSDE 5009

Electrical Principles, Methods and
Simulation



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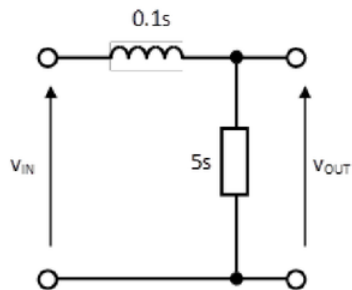
Introduction

The Main aims of this assignment is to develop my knowledge and analytical skills when it comes to the evaluation of all of the electrical circuits and the electronic system simulations which would have been developed.

The objectives of this assignment are to demonstrate my ability of converting mathematical calculations into a format which is useable for matlab and also to create mathematical models by making the use of transfer functions and then using matlab in order to predict its performance.

Task 1

The selected values for the components are 0.1H for the inductor and a 5 Ω resistor. The circuit can be seen below in figure 1.



(Figure 1)

$$T = L/R = 0.02$$

$$c = 1/T = 50$$

$$H(s) = 1/0.02s + 1$$

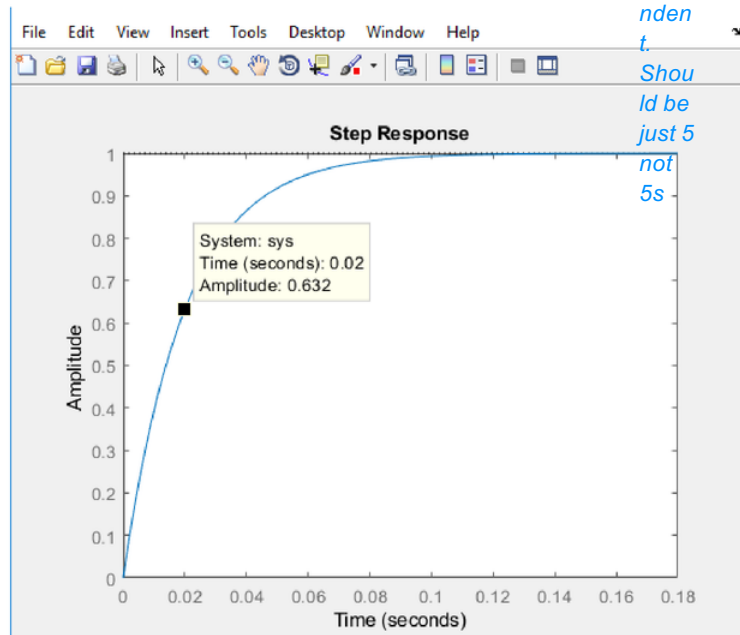
The above equation will now be inputted into matlab as shown with the below num and den.

Num[1] ;

Den[0.02 1] ;

Step(num, den);

Below in figure 2 displays the time constant in practice and it matches the theory value also.



(Figure 2)

's'
shoul
d not
be
linke
d
with
the
resist
ance
as it
is not
time
or
frequ
ency
depe
nden
t.

Shou
ld be
just 5
not
5s

good

Now the cut off frequency will be displayed through the aid of matlab.

Cut off frequency = $H(s) = \omega_c/s + \omega_c$

$H(s) = 50/s + 50$

*brackets are needed to correctly
express this transfer function here*

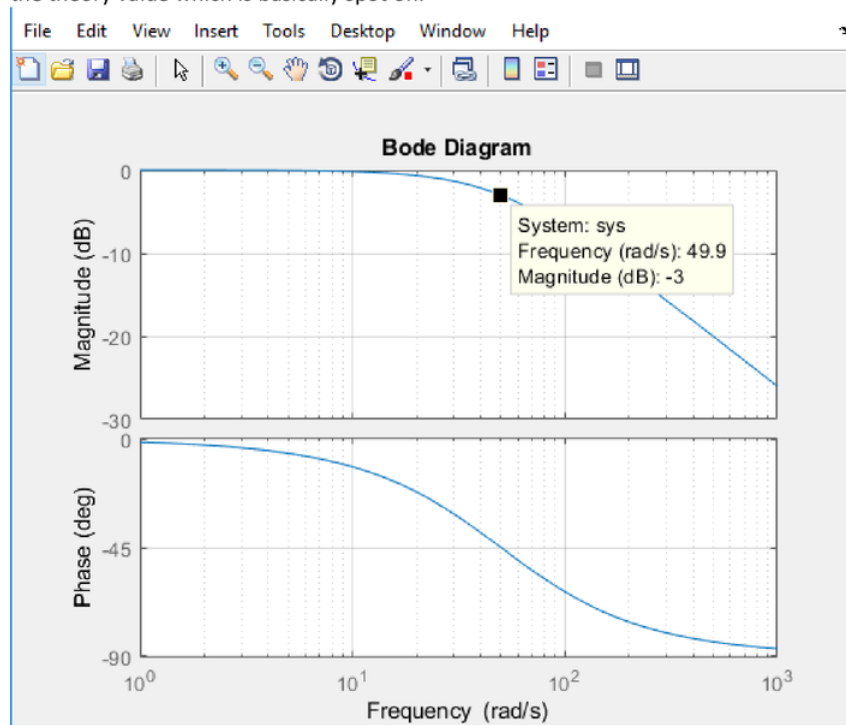
Num = [50];

Den = [1 50]; *correct*

Bode(num, den);

Grid

Below in figure 3 displays the cut off frequency at -3dB. The frequency is 49.9 rad/s which is 0.1 off the theory value which is basically spot on.



roll off?

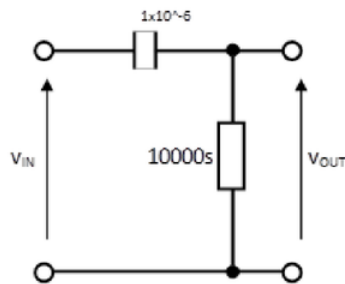
(Figure 3)

Comparing both of these results from matlab to the theory the values are basically the same. There is basically no error or difference between the theory and simulated values.

*you could have measured
the roll off as 20dB per
decade and you could
have explained the
expected the phase shift*

Task 1b

As show below in figure 4 is the laplace model with the selected values.



(Figure 4)

's' should not be linked with the resistance as it is not time or frequency dependent.

The transfer function for this equation is

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

*Marks were available for deriving the t.f.
Brackets are missing*

$$T = RC = 10,000 \times 1 \times 10^{-6} = 0.01 \text{ seconds}$$

$$\omega_c = 1/RC = 1/0.01 = 100 \text{ rad/s}$$

$$H(s) = \frac{0.01}{0.01s+1}$$

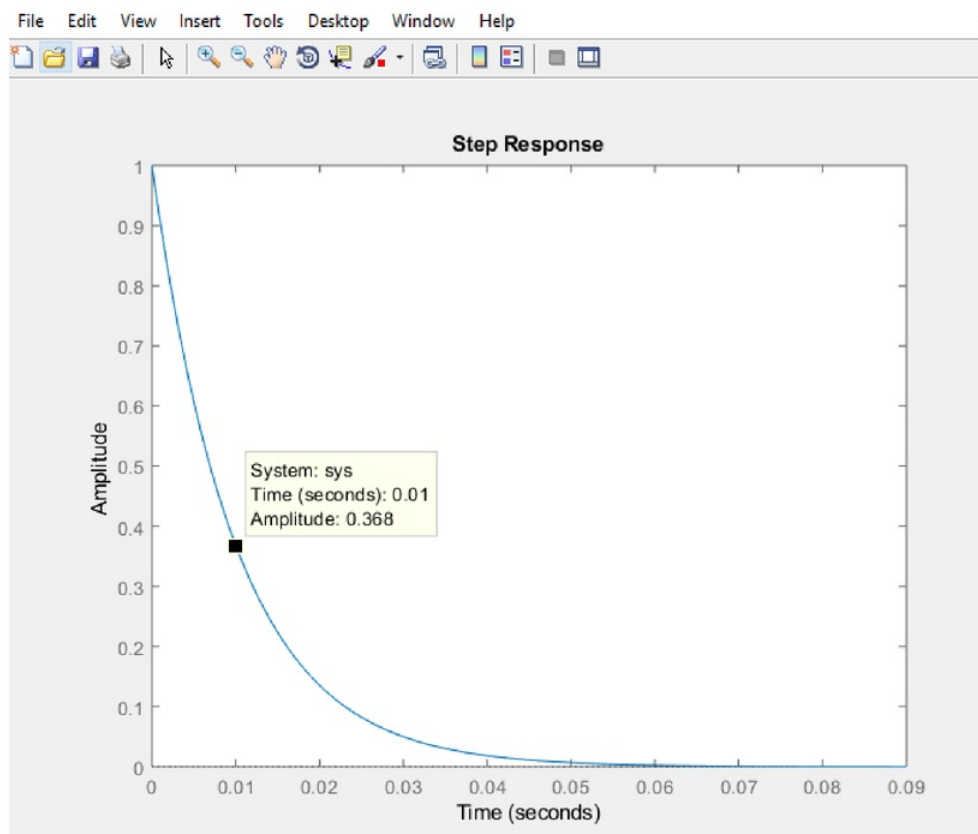
's' is missing

$$H(s) = \frac{s}{s+100}$$

The below instructions were then entered into matlab and below in figure 5 is the result.

```
Num[ 0.01 ] ;  
Den[ 0.01 1 ] ;  
Step(num, den)
```

wrong type of bracket



good

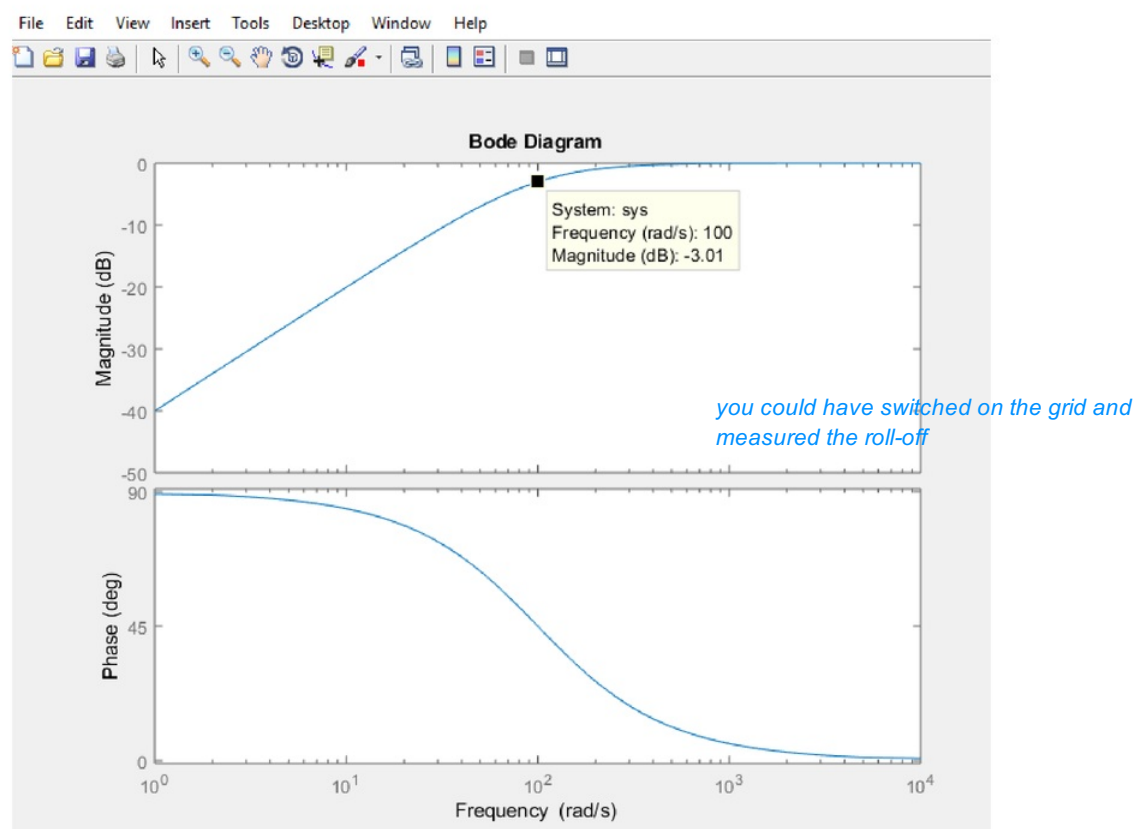
(Figure 5)

As shown above in figure 5 is a simulated matlab the time in the above graph was calculated at 0.01 and in actual practice it is also 0.01.

The following code below in figure 6 was entered into matlab and gave the result of figure 7. In figure 7 the aim is to find out the cut off frequency which has been calculated as 100 rads/s in the above calculation. As shown in figure 7 the cut off frequency which occurs at -3dB is 100 rads/s which matches the theory value.

```
>> num=[0.01 0];  
>> den=[0.01 1];  
>> bode(num,den)
```

(Figure 6)

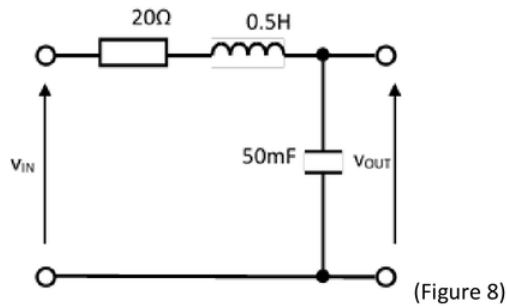


(Figure 7)

*you could
have
commented
on the phase
shift*

Task 2

The laplace model is shown below in figure 8. The transfer function for this circuit is as followed below.



$$H(s) = 1/LC / (s^2 + R/Ls + 1/LC)$$

$$R/L = 20/0.5 = 40$$

$$1/LC = 40000$$

$$\omega_m = \frac{1}{\sqrt{0.5 \times 50 \times 10^{-6}} - 0.5 \left(\frac{20}{0.5}\right)^2} = 197.98 \text{ rads/s}$$

$$\omega_o = 1/\sqrt{LC} = 200 \text{ rads/s}$$

$$Q\text{-Factor} = 1/20 \sqrt{0.5/50 \times 10^{-6}} = 5$$

$$H(s) = 40000/s^2 + 40s + 40000$$

$$\zeta = 20/2\sqrt{50 \times 10^{-6}/0.5} = 0.1$$

This is underdamped. This is known as the equation above tells us that.

For $\zeta=1$, $R = 2\sqrt{L/C} = 200$.

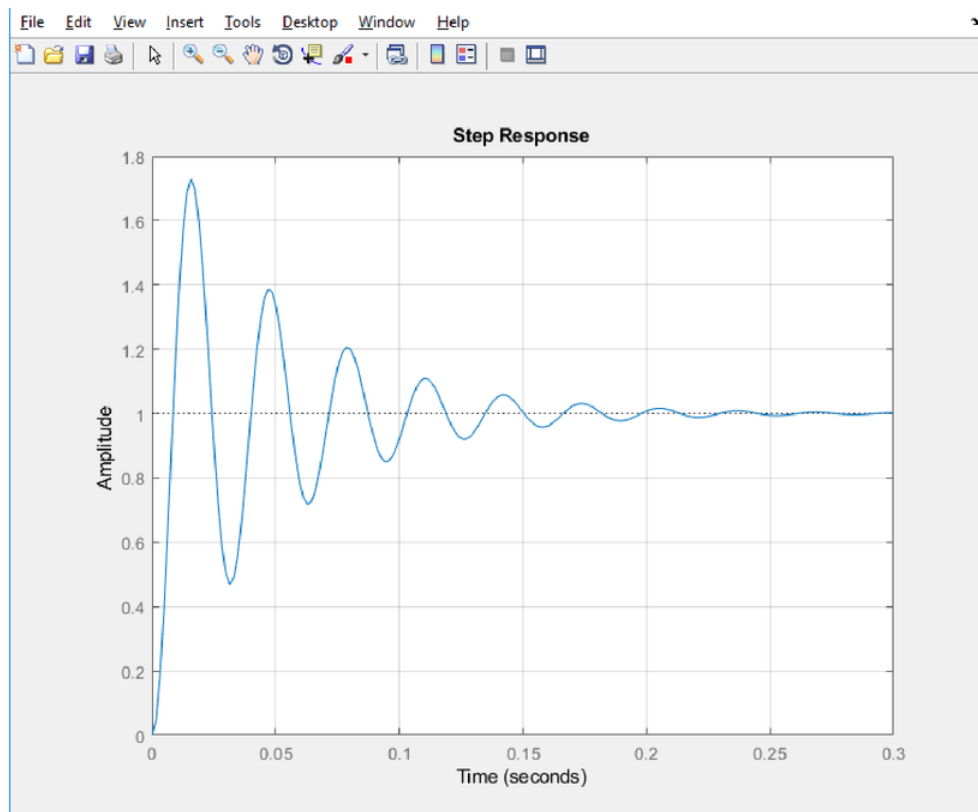
Below is the formula that was put into matlab in order to simulate figure 10.

```

Editor - H:\MATLAB\assignment1_task2a.m
assignment1_task2a.m  ✕  +
1 -   num = [40000];
2 -   den = [1 40 40000];
3 -   step(num,den);
4 -   grid on
5

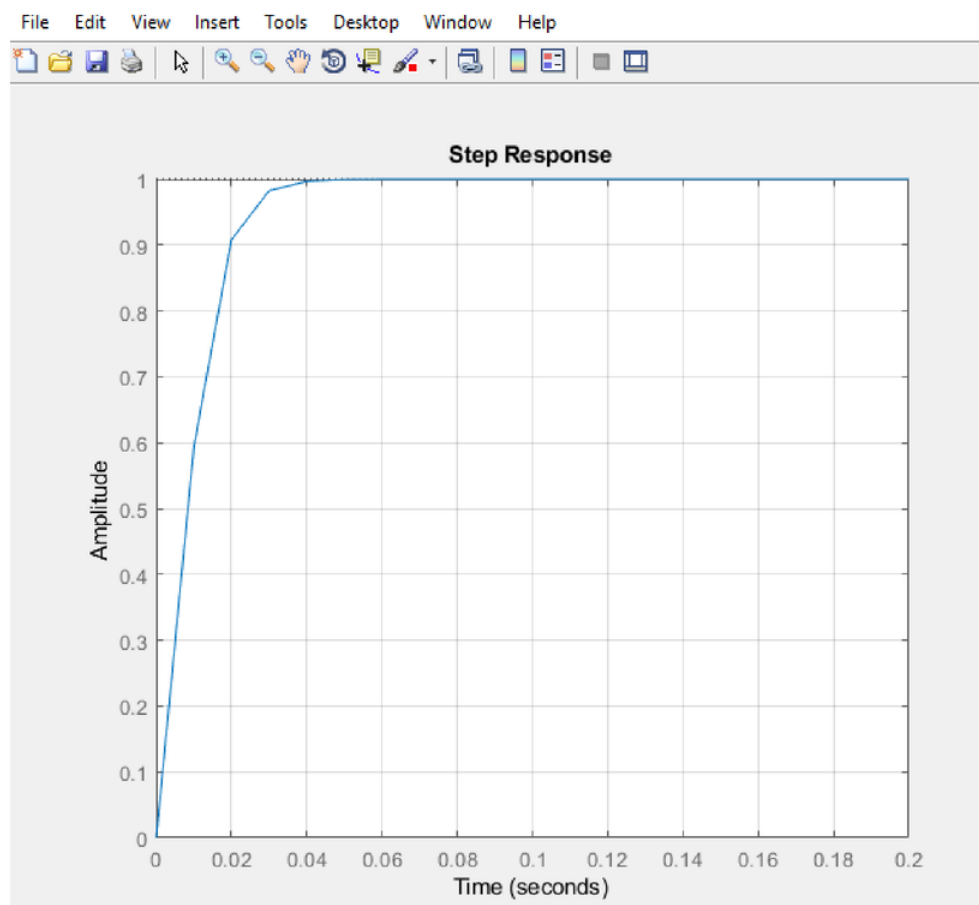
```

(Figure 9)



(Figure 10)

As shown above in figure 10 the simulated response is under damped. The dampening can be changed by altering the value of the resistance which is shown below in figure 11 where the resistance value has been altered in order to give critical damping.



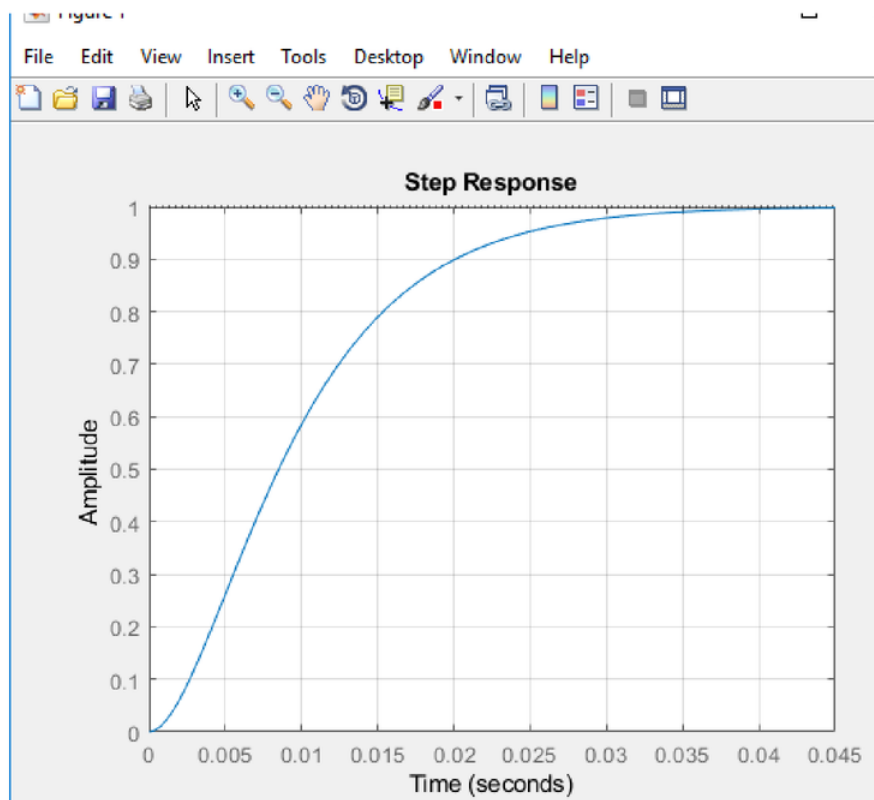
(Figure 11)

As shown above this is critical damping. This has been achieved by altering the second den value from 40 to 400 and then it displays critical damping. The change has actually only changed the value of resistance to 200 however when putting it into the formulas it gives a value of 400. As shown in figure 12 is the edited matlab code for critical damping.

```
Editor - H:\MATLAB\assignment1_task2a.m
assignment1_task2a.m
1 - num = [40000];
2 - den=[1 400 40000];
3 - step(num,den)
4 - grid on
```

(Figure 12)

As shown below in figure 13 this is critical damping. This is done by modifying the resistance again giving a different value for the matlab code. Change the resistance value to anything over 200 will result in critical damping and the step response in figure 13 proves that.



(Figure 13)

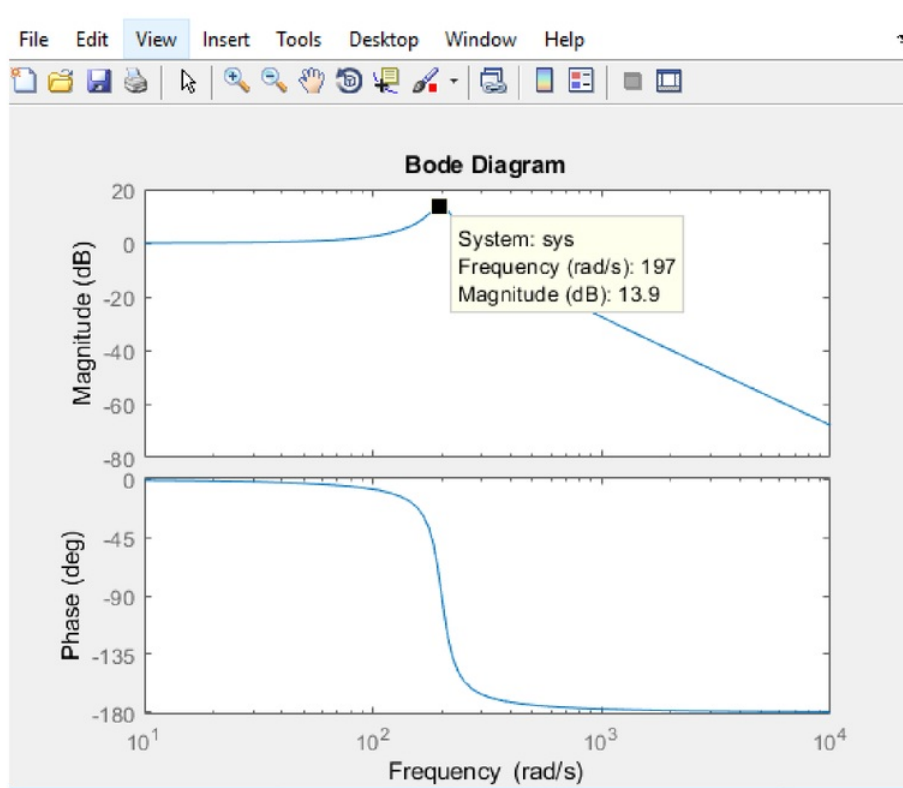
Below in figure 14 is the matlab formula entered for critical damping.

```

Editor - H:\MATLAB\assignment1_task2
assignment1_task2a.m
1 - num = [40000];
2 - den=[1 410 40000];
3 - step(num,den)
4 - grid on
    
```

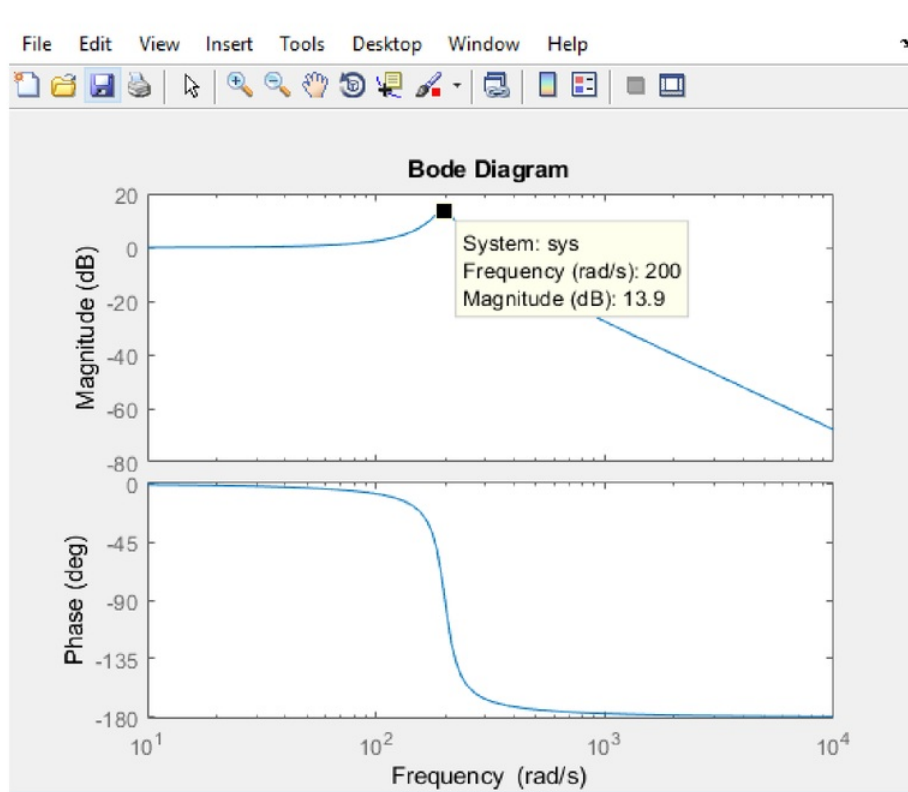
(Figure 14)

Below in figure 15 is the ω_m value which was simulated using matlab, as seen in the figure it is 197 rads/s. This matches the theoretical value which was calculated to be 197 rads per second.



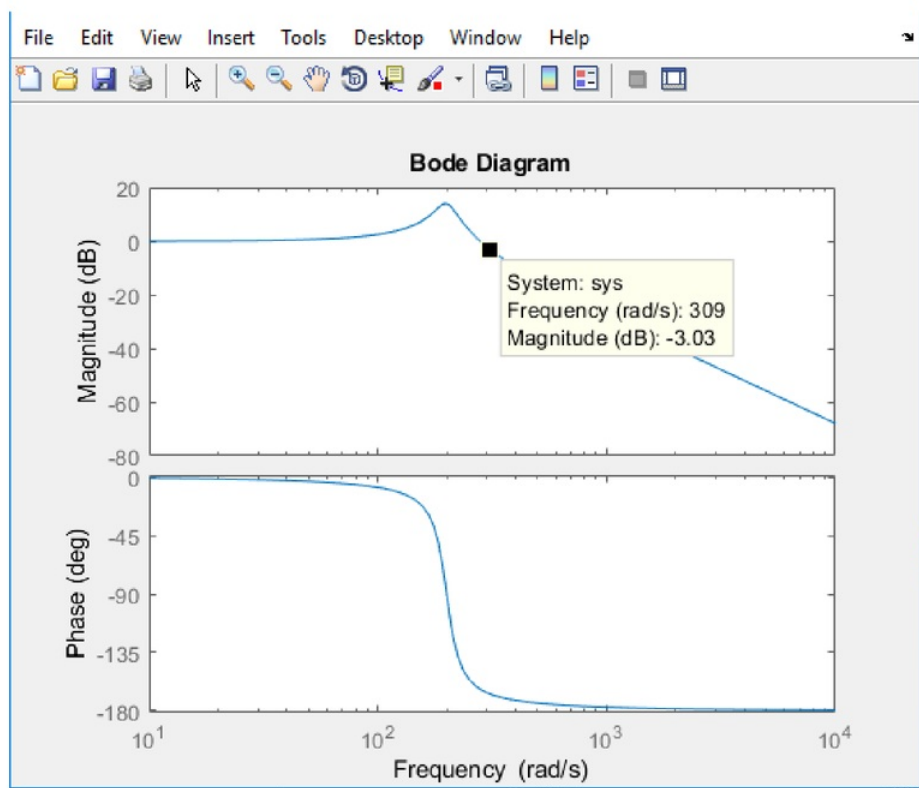
(Figure 15)

The calculated value for ω_0 was 200 rad/s and as shown in figure 16 this is spot on match when simulated using matlab.



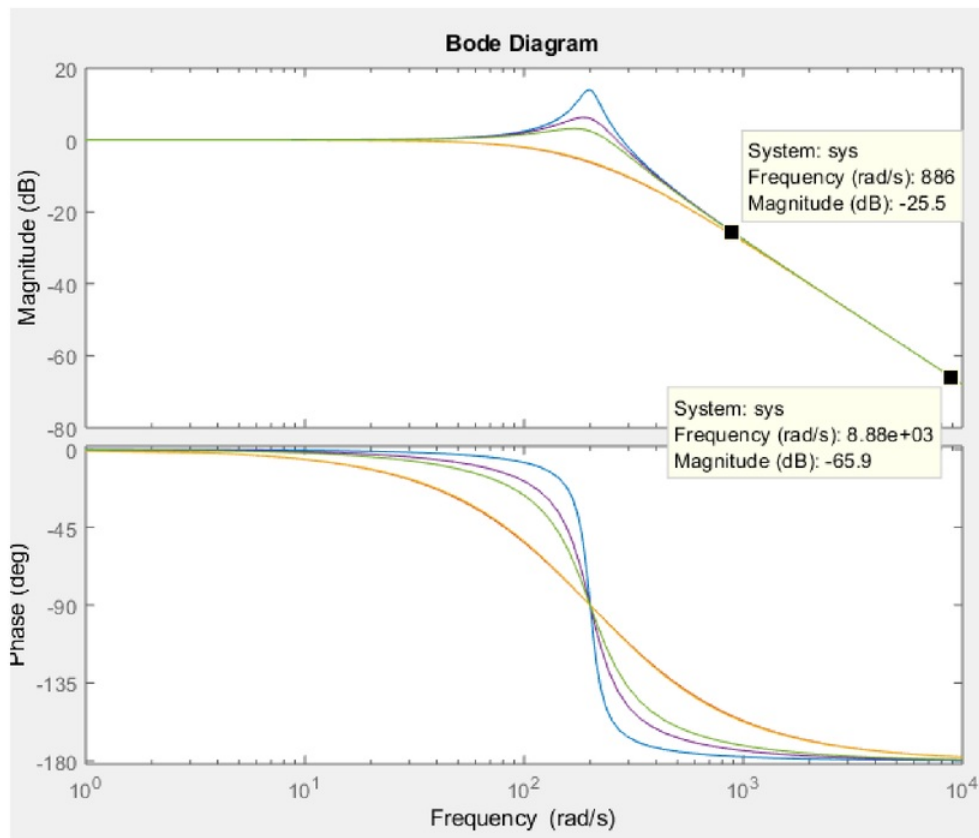
(Figure 16)

As shown below in figure 17 is the cut off frequency which occurs at -3dB which is 309 rad/s which is very close to the calculated value.



(Figure 17)

As shown below in figure 18 is the affect of varying the resistance for this filter. Figure 18 shows that the phase shift is better as R is increased, the response of the circuit gets better as the maximum frequency decreases. Figure 18 is a perfect example of how the circuits performance is better as R is increased.



comment on phase shift

40DB per decade

```
Num=[40000];
```

```
Den=[1 40 40000];
```

```
Bode(num,den)
```

Hold ON

```
Num=[40000];
```

```
Den=[1 100 40000];
```

```
Bode(num,den)
```

Hold ON

```
Num=[40000];
```

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```
Den=[1 200 40000];
```

```
Bode(num,den)
```

Hold ON

```
Num=[40000];
```

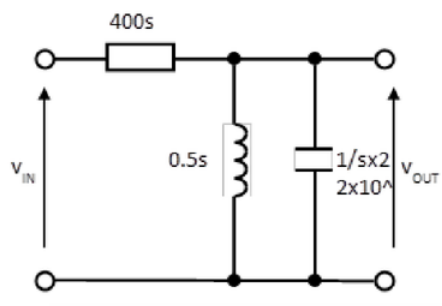
```
Den=[1 150 40000];
```

```
Bode(num,den)
```

Hold ON

Task2b

Below in figure 19 is the laplace model of the circuit. The theoretical values have been calculated in order to produce a matlab response and compare results.



(Figure 19)

$$H(s) = s \times 1 \div rc / s^2 + s \div RC + 1 \div LC$$

$$1/RC = 1/400 \times 2 \times 10^{-6} = 113.636$$

$$1/LC = 1/0.5 \times 2 \times 10^{-6} = 90909.091$$

$$H(s) = sx113.636/s^2 + s113.636 + 90909.091$$

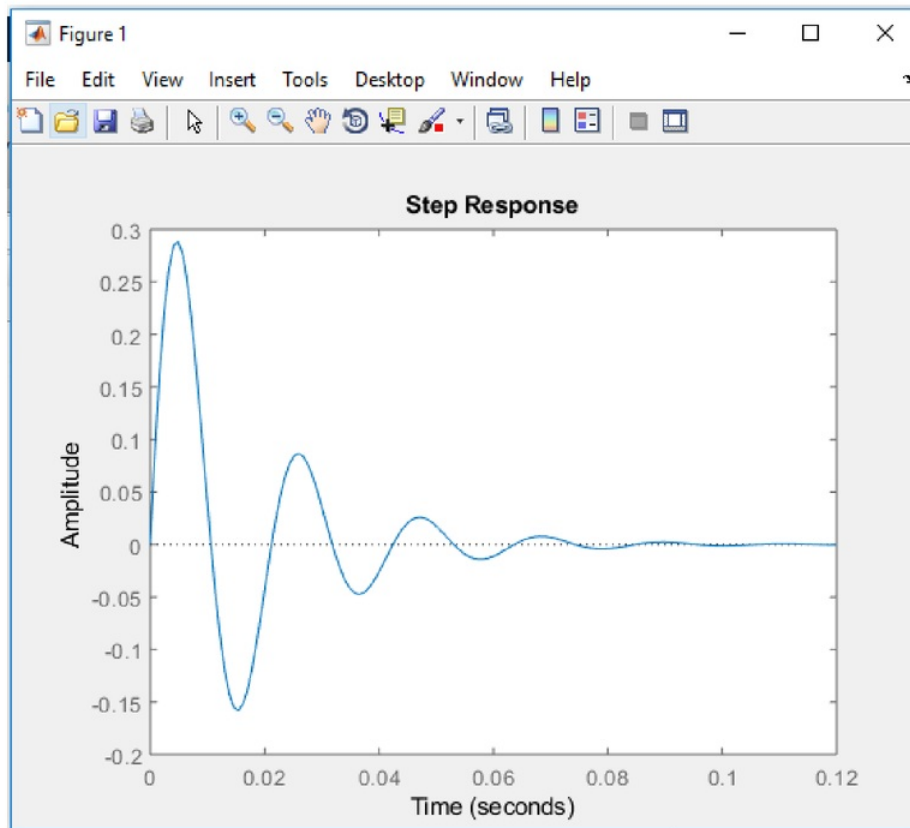
$$\omega_o^2 = 90909.091$$

$$\omega_o = 301.511$$

$$\beta = 113.636$$

$$Q_{factor} = \omega_o / \beta = 2.6533$$

Below in figure 20 shows the response of this circuit. This circuit is critical damping. In figure 21 shows the matlab code entered in order to produce the response.

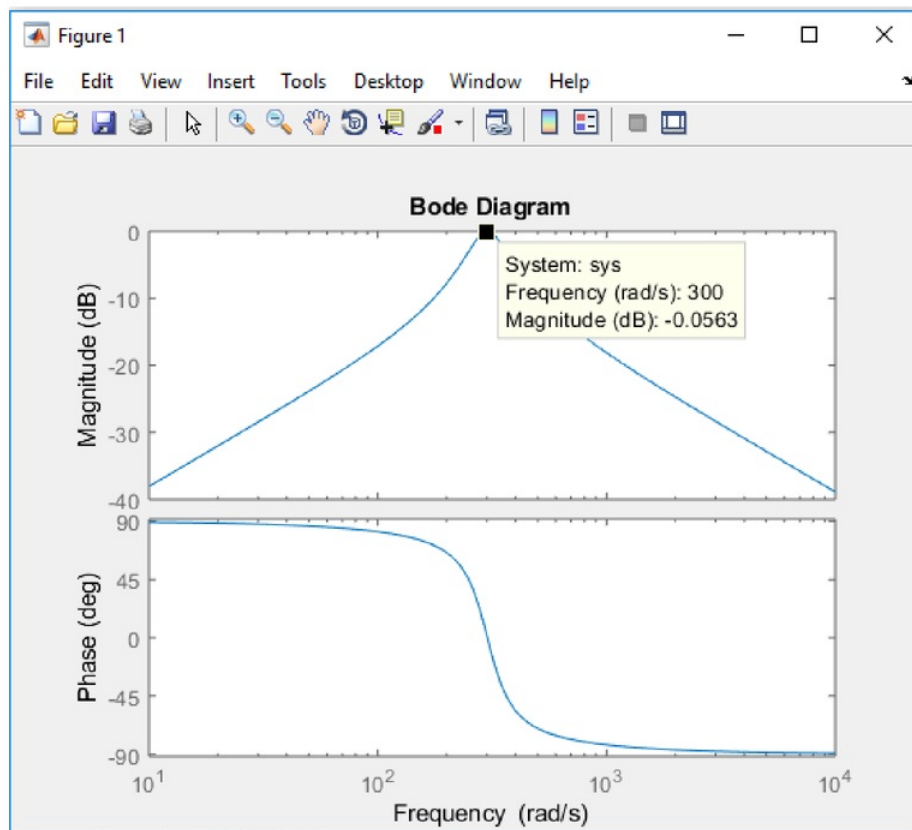


(Figure 20)

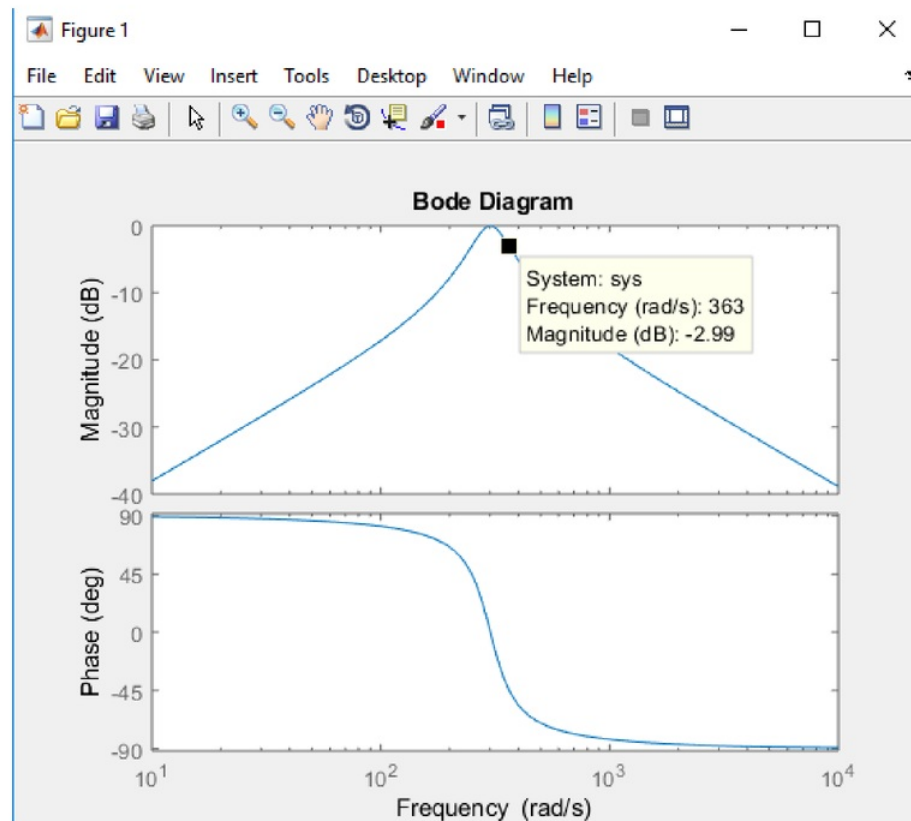
```
assignment1_2b.m  x  +
1 -   num=[113.636 0];
2 -   den=[1 113.636 90909.091];
3 -   step(num,den);
4 -   |
```

(Figure 21)

As shown below in figure 22 is the highest point of frequency which is 300 rads/s, this is basically the same as the calculated value which is 301 rads/s .

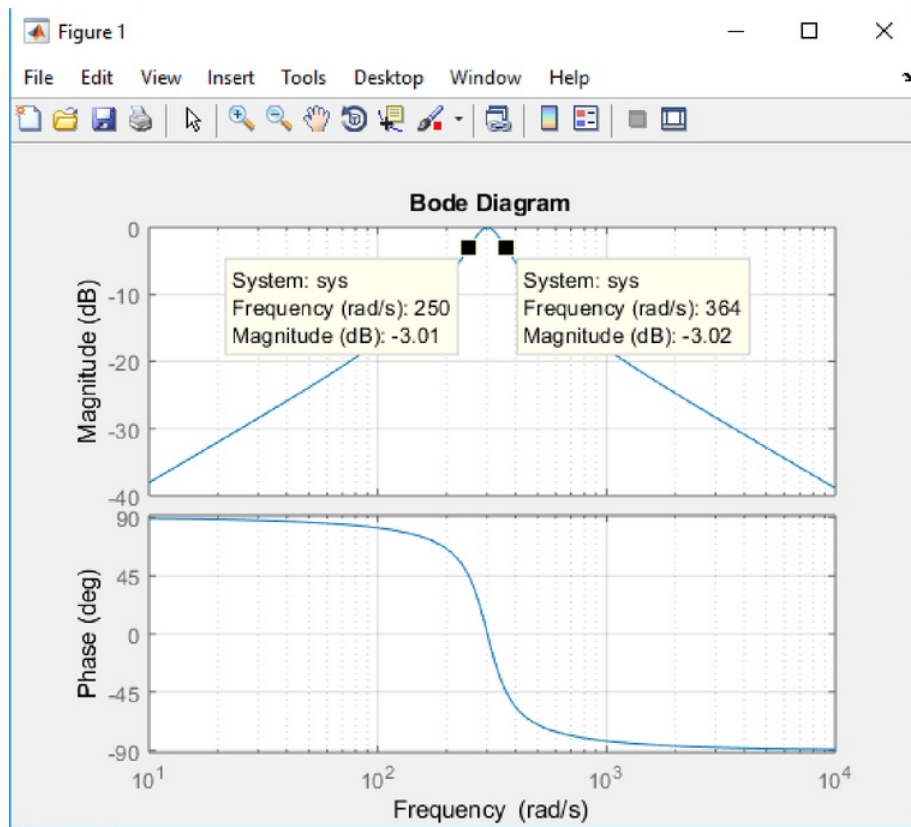


(Figure 22)



(Figure 23)

As shown above in figure 23 is the cut off frequency which occurs at -3dB and is 363 rads/s which is very close to the calculated value. Slight differences maybe due to human calculation error.

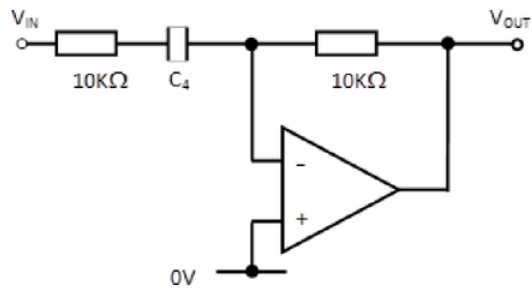


(Figure 24)

As shown above is the bandwidth which works out to be 114 rads/s which is the same as the calculated value with an error of just 1 rad/s.

Task 3

For the circuit below in figure 24 C4 will be 4nF. Now using theory the transferfunction will be started and ω_c will be worked out in order to give a matlab equation for comparison.



(Figure 24)

$$K = 10000/10000 = 1$$

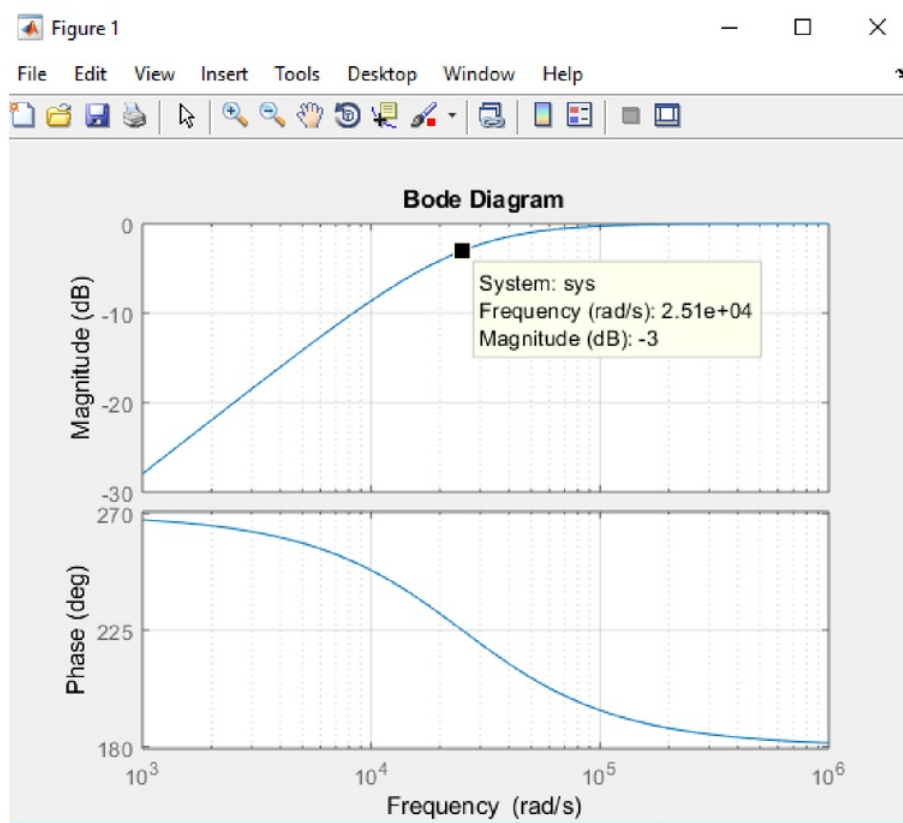
$$\omega_c = 1/4 \times 10^{-9} \times 10000 = 25000 \text{ Rads/s}$$

$$H(s) = -1/(s + 25000)$$

In figure 25 is the matlab formula which was entered in order to create figure 26.

```
Editor - H:\MATLAB\assignment1_2b.m
assignment1_2b.m
1 - num=[-1 0];
2 - den=[1 25000];
3 - bode(num,den);
4 - grid
5 -
```

(Figure 25)

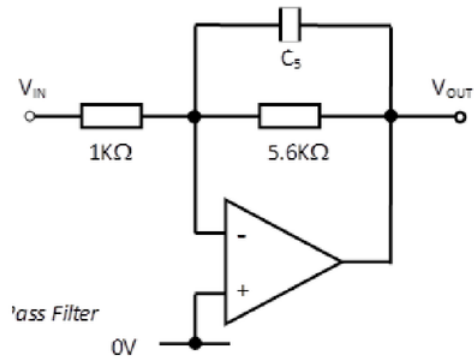


(Figure 26)

As shown above in figure 26 is the ω_c frequency value which is shown as 25000 which matches the value which has been calculated.

Task 3b

In figure 27 below is the circuit under analysis. The chosen value for C_5 is 400nF. Now using theoretical analysis the matlab formulas will be derived from this.



(Figure 27)

$$K = 5.6/1 = 5.6$$

$$\omega_c = 1/400 \times 10^{-9} \times 5600 = 446.428 \text{ rads/s}$$

$$H(s) = -5.6 (446.428/s + 446.428)$$

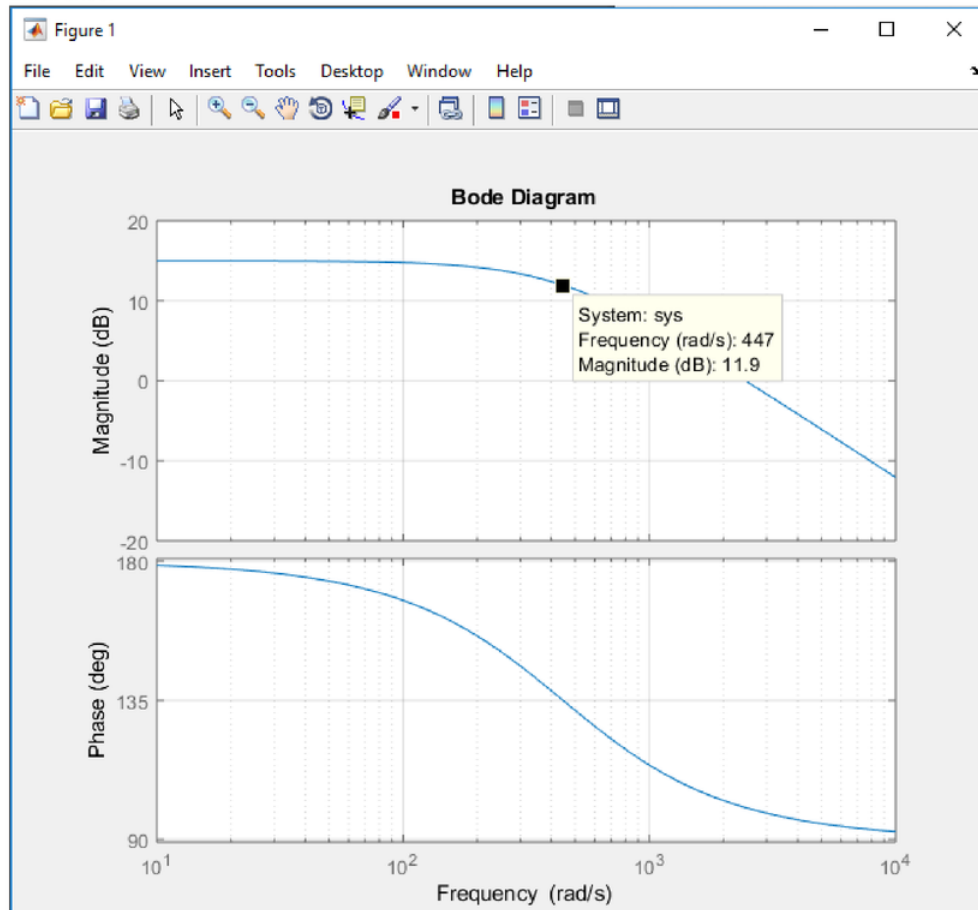
Below in figure 28 is the matlab formula which was used in order to create figure 29.

```

Editor - H:\MATLAB\assignment1_2b.
assignment1_2b.m  x  +
1 - num=[-5.6* 446];
2 - den=[1 446];
3 - bode(num,den);
4 - grid
5
    
```

(Figure 28)

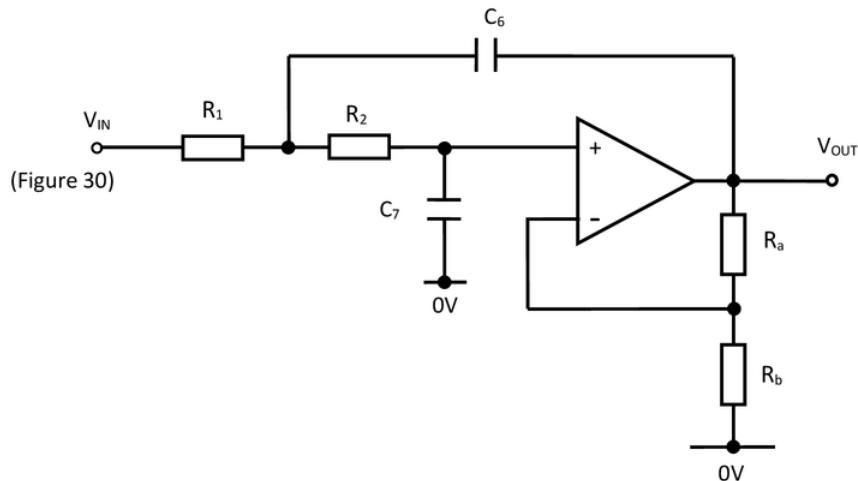
As shown below in figure 29 shows the ω_c value which is displayed as 447 rads/s. This is basically the same as the calculated value of 446.428 rads/s. Rounding errors could be due to the 1 rad/s difference.



(Figure 29)

Task 4a

In the figure below is a second order low pass filter. The component values will be calculated and then a matlab simulation will be run in order to do a critical analysis of the circuit.



Below are the calculations which are used in order to create the matlab simulation.

For $\omega_c = 446 \text{ rads/s}$

Let $c = 100\text{nf}$

$$R1 = 1 / (446 \times 100 \times 10^{-9}) = 22421 \Omega$$

$$R1 = R2 = 22421 \Omega$$

$$K \text{ for butterworth} = 1.586 = 4\text{db}$$

$$\text{If } R_B = 2500 \Omega$$

$$R_A = (k-1) \times R_B = (1.586-1) \times 2500 = 1465 \Omega$$

$$Q = 1/3 - k = 1/3 - 1.586 = 0.707$$

$$\omega_c / Q = 446 / 0.707 = 630.8$$

$$H(S) = 1.586 \times (10^3)^2 / S^2 + 630.8 + (10^3)^2 = 1586000 / S^2 + 630 + 1000000$$

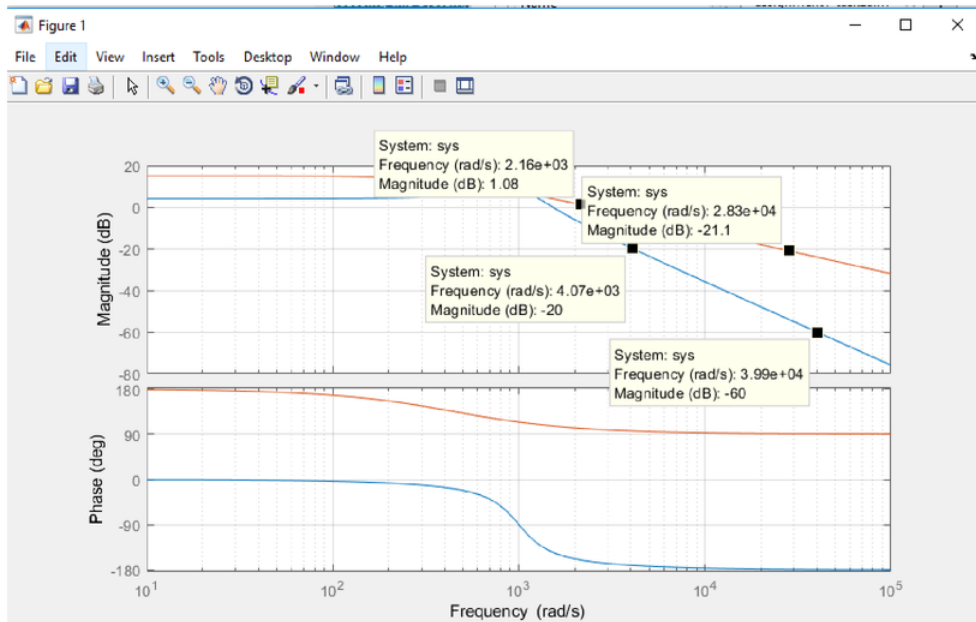
The num and den is for the circuit seen in figure 30 which will be compared with the circuit in figure 27.

$$\text{Num} = [1586000];$$

$$\text{Den} = [1 \ 603 \ 1000000];$$

$$\text{Bode}(\text{num}, \text{den})$$

As shown below in figure 31 the blue line is the second order circuit and the orange line is the first order circuit. As seen by the tags there is a rate of change for the first order circuit is 20DB per decade which is as expected as filters have a rate of roll off of 20 DB per decade per order. As seen by the blue line it is 40DB per decade which is expected due to it being a second order filter.



(Figure 31)

Below in figure 32 is the formulas that were entered into matlab in order to produce figure 31.

```

1 - num=[1586000];
2 - den=[1 603 1000000];
3 - bode(num,den)
4 - grid on
5 - hold on
6 - num=[-5.6* 446];
7 - den=[1 446];
8 - bode(num,den)
9 - grid on
10 - hold on
    
```

(Figure 32)

4b

Following below are the calculations which have been used in order to gather the matlab formulas which are used to simulate figure 33.

$$K = 5.6/1 = 5.6$$

$$W_c = 1/400 \times 10^{-9} \times 56000 = 446.428 \text{ rads/s}$$

$$H(s) = -5.6 (446.428/s + 446.428)$$

Following below is what formula which was entered into matlab along with the matlab code from task 3a.

```
Num=[-5.6 * 446];
```

```
Den=[1 446];
```

```
Bode(num,den);
```

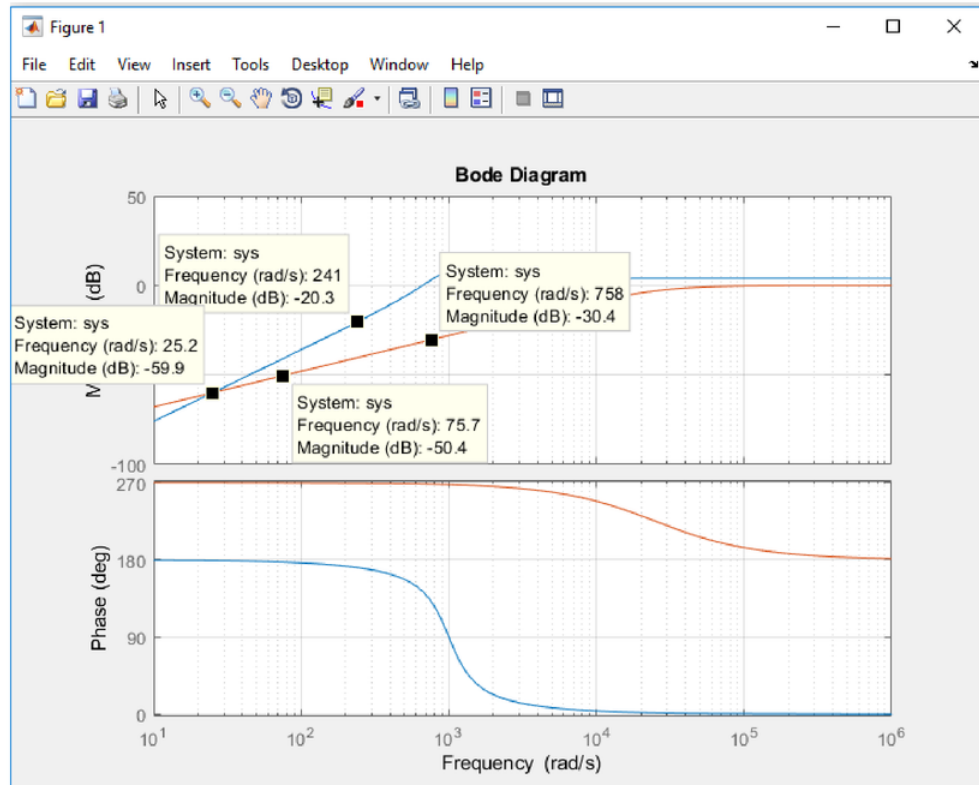
```
Grid
```

As shown below in figure is what formula was entered into matlab.

```
1 - num=[1.586 0 0];  
2 - den=[1 630 1000000];  
3 - bode(num,den);  
4 - hold on  
5 - num=[-1 0];  
6 - den=[1 25000];  
7 - bode(num,den);
```

(Figure 33)

As shown below is the simulated matlab bode diagram, the orange line is the first order circuit from task 3 and the blue line is the second order circuit. As shown in figure 34 the second order circuit (the blue line) has a rate of roll off of 40DB per decade compared to the orange line which is the first order circuit which has 20DB perdecade. This is due to the increased number of components in the circuit which gives the circuit a better response.



Conclusion and recommendations

To conclude this assignment there is a clear noticeable difference between the characteristics of a first order circuit compared to a second order circuit. Shown in the evidence from this assignment there is a clear correlation between the performance of a filter and the order that filter is for example there is a vast difference between a first order filter performance and a 9th order filter performance.

With RLC circuits there is also a clear relation between the varying of resistance and what type of damping the circuit is. This was demonstrated in tasks 2a and 2b. This shows how a circuit can be manipulated by changing circuit component values and demonstrates how to get the best performance out of a circuit.

Finally the recommendations for this assignment would be maybe a research part to this assignment in order to develop further knowledge and understanding of the circuits which have been analysed. Also maybe a further analysis of certain circuits could be done instead of having multiple circuits just have in depth analysis of fewer circuits.

FINAL GRADE

GENERAL COMMENTS

51 / 100

Instructor

PAGE 1

PAGE 2

PAGE 3

Text Comment. avoid personal references, always write in the third person.

PAGE 4

Text Comment. 's' should not be linked with the resistance as it is not time or frequency dependent. Should be just 5 not 5s

Text Comment. What is c? did you mean wc? What are the units?

Text Comment. this transfer function should have been derived

Text Comment. correct

Text Comment. wrong type of bracket

Text Comment. good

PAGE 5

Text Comment. brackets are needed to correctly express this transfer function here

Text Comment. correct

Text Comment. roll off?

Text Comment. you could have measured the roll off as 20dB per decade and you could have explained the expected the phase shift

PAGE 6

Text Comment. 's' should not be linked with the resistance as it is not time or frequency dependent.

Text Comment. Marks were available for deriving the t.f. Brackets are missing

Text Comment. seconds

Text Comment. rad/s

Text Comment. 's' is missing

Text Comment. wrong type of bracket

PAGE 7

Text Comment. good

PAGE 8

Text Comment. you could have switched on the grid and measured the roll-off

Text Comment. you could have commented on the phase shift

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GRADING FORM: CSG-RUBIC

PHILLIP ROWE

51

RESEARCH-INFORMED LITERATURE



N/A

KNOWLEDGE AND UNDERSTANDING



Sections 2, 3: Explanations for Electric Circuits – Some descriptions and explanations briefly given. The presentation quality of your equations would have been improved by using an equation editor. Formulae could have been stated first and explained before component values used to produce theoretical results. (5/10) Sections 4, 5: Explanations for Electronic Systems – Very little explanations given. (4/10)

9

ANALYSIS



Sections 2, 3: Analysis, Modelling and Testing of Electric Circuits - Good evidence of analysis. There are however, some errors which have not been spotted and not all tasks are complete. Further marks were available for additional measurements and comments on results. (11/20) Sections 4, 5: Analysis, Modelling and Testing of Electronic Systems - Contains some attempt at analysis. Further marks were available for better accuracy in calculations and a more detailed analysis of results would have shown that errors existed. (10/20) Section 6: Conclusions and recommendations – Some helpful conclusions offered (although the assignment did not cover a 9th order filter) but you have misunderstood the purpose of the recommendations. (5/10)

26

PRACTICAL APPLICATION AND DEP.



Sections 2,3,4,5: Use of Matlab – Generally good. (7/10) Sections 2,3,4,5: Accuracy and Presentation Quality of Results – Mostly accurate with some errors in later tasks. Results are mostly well presented but grid should always be switched on in Matlab and you could have summarised your results in a table for comparison between theory and simulation. (6/10)

13

SKILLS FOR PROFESSIONAL PRAC.



Section 1: Introduction: Briefly stated but no explanation on exactly what is to be done. Should be written in the third person. (1/5) All sections:

3

Overall Report Quality - Some parts are well presented but others are not. Report should be structured as stated in the brief and equations should be presented more clearly. (2/5)