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A Series of Module has been designed and developed by author mentioned above with full copyright for a course of **Control System** to demonstrante the concept of control system and its implementation in real life to second year Aerospace engineering students at Tribhuwan University.

MODULE VII: Frequency Response

Frequency response is coined to the examination of the response of a system in steady state to an input to a sinusoidal signal. Bode, Nyquist, Polar Plots are used for frequency domain visulaization.

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7.1 Frequency Domain Characterization of the system

```
%Defining the system
syms s w
sys=1000/(s*(1+0.1*s)*(1+0.001*s));
sys_w=subs(sys,s,1j*w)
```

sys_w =

$$-\frac{1000\,\mathrm{i}}{w\left(1+\frac{w\,\mathrm{i}}{10}\right)\left(1+\frac{w\,\mathrm{i}}{1000}\right)}$$

```
Magnitude=abs(sys_w)
```

Magnitude =

$$\frac{1000}{\left|1+\frac{w\,\mathrm{i}}{10}\right|\,\left|1+\frac{w\,\mathrm{i}}{1000}\right|\,|w|}$$

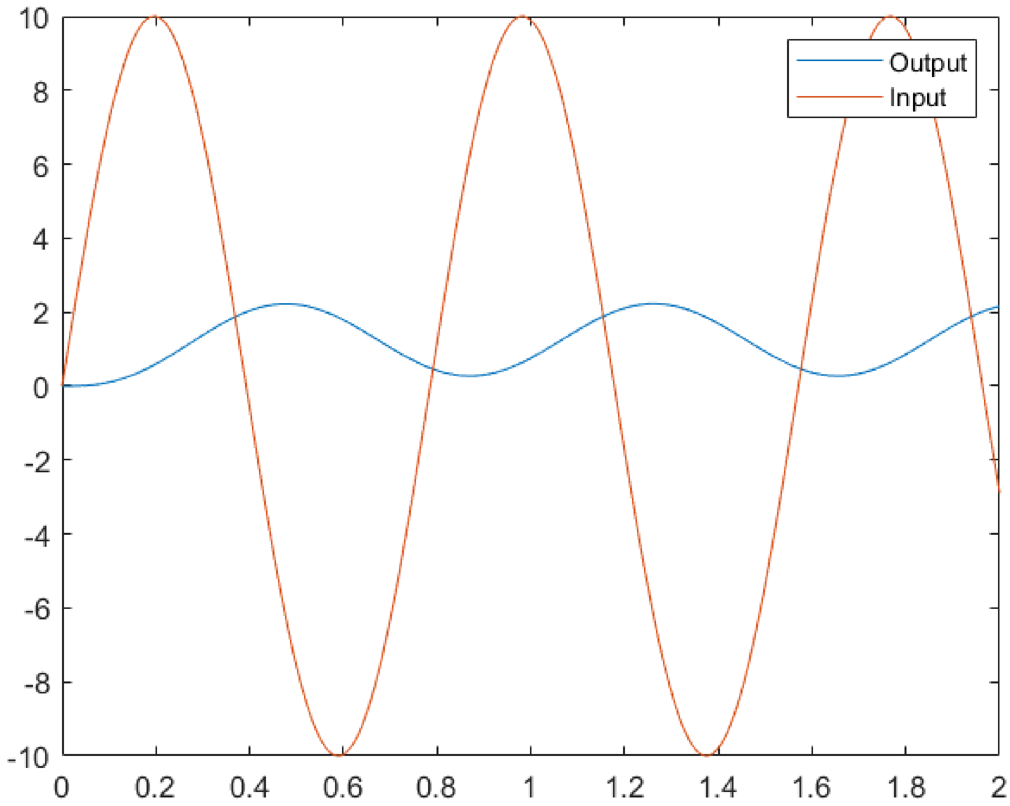
```
Phase=angle(sys_w)
```

Phase =

$$\mathrm{angle}\left(-\frac{\mathrm{i}}{w\,\left(1+\frac{w\,\mathrm{i}}{10}\right)\,\left(1+\frac{w\,\mathrm{i}}{1000}\right)}\right)$$

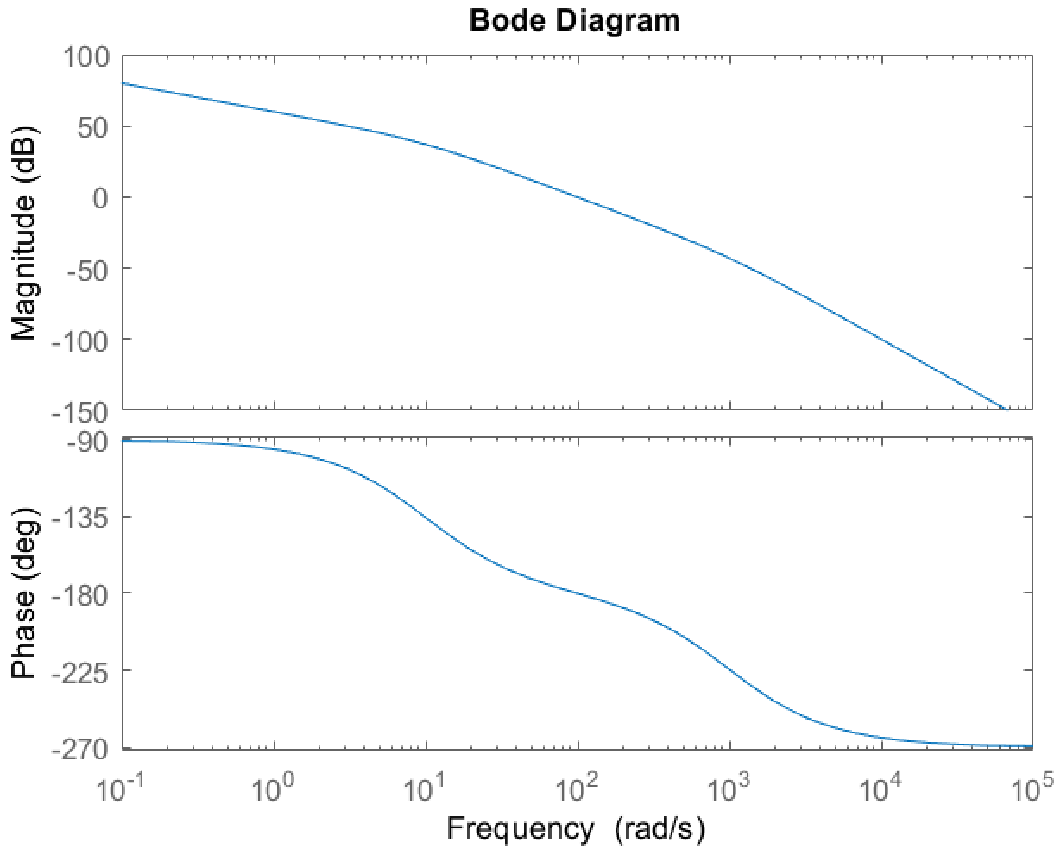
7.2 Sinusoidal Response

```
s=tf('s');
sys=10/(s*(s+10));                              % Define LTI System
t = 0:0.001:2;                                   % Time Vector
u = 10*sin(8*t);                                 % Forcing Function
y = lsim(sys, u, t);                             % Calculate System Response
figure
plot(t, y)
hold on
plot(t,u);
legend Output Input
hold off
```

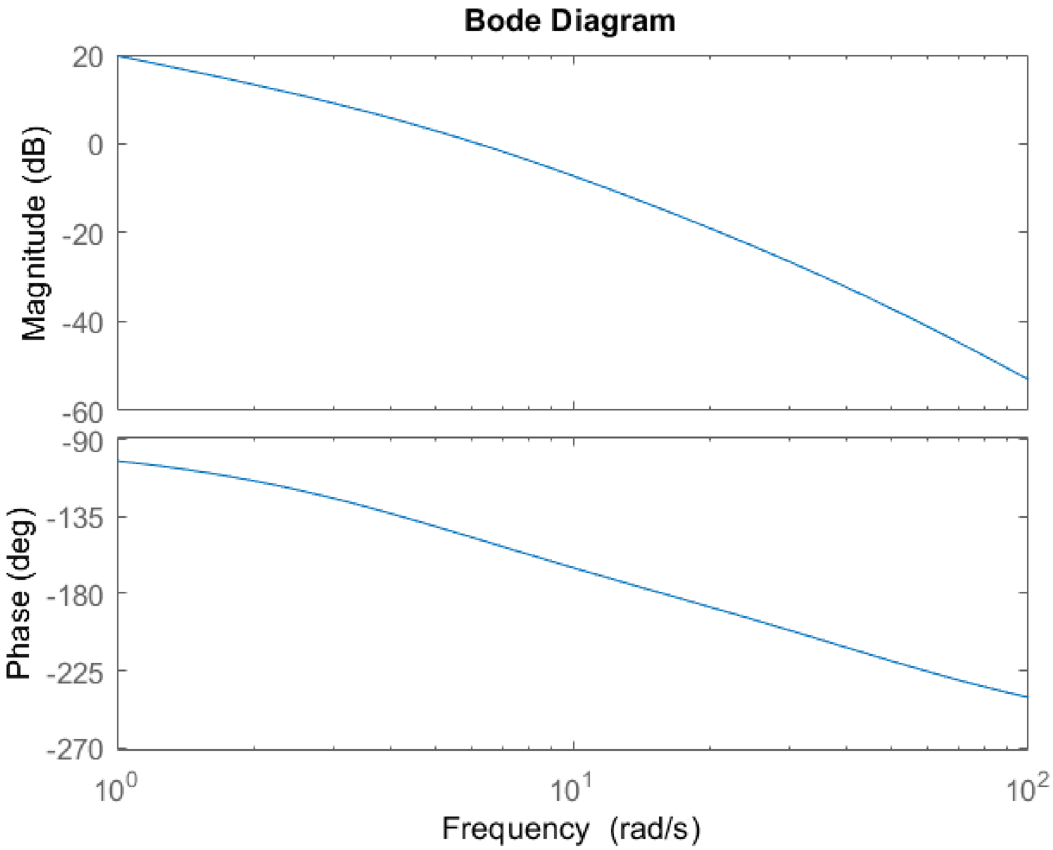


7.3 Bode Plot

```
%define the system
s=tf('s');
G1=1000/(s*(1+0.1*s)*(1+0.001*s));  % Define system in s-domian
% Plot Bode using bode command
bode(G1)
```



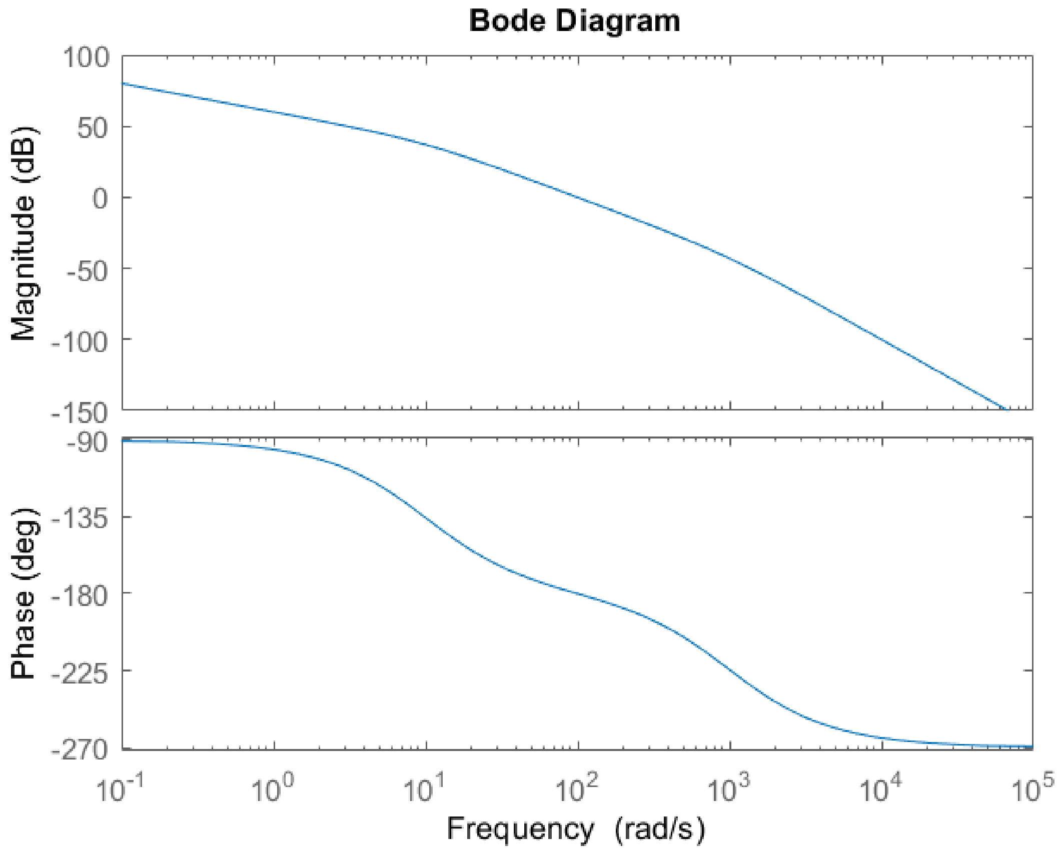

```
%-----------------------------------------------------------
% Some Other Examples
%-----------------------------------------------------------
 G=10/(s*(1+0.2*s)*(1+0.02*s));
 %bode(G)
 % To plot bode within certain frequency range
 bode(G,{1,100})
```



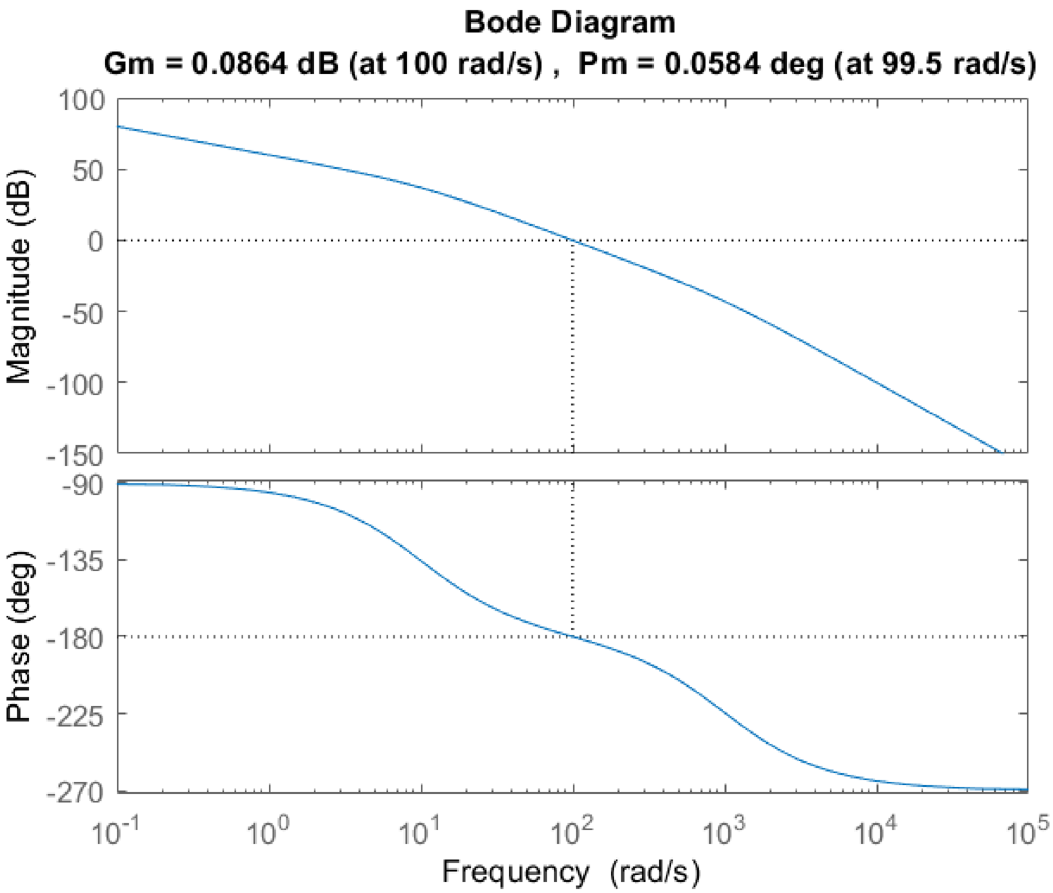

```
%  G2=512*(s+3)/(s*(s^2+16*s+256));
%  bode(G2)
% G3=(4*s+40)/((s^2+4*s+25)*(s^2+50*s));
% bode(G3)
% G4= 250/(s*(s+50)*(s+5));
% bode(G4)
%  G5=(20*s+200)/((s^2+4*s+25)*(s^2+40*s));
%  bode(G5)
```

7.4 Perfomance Specifications

```
%define the system
s=tf('s');
G=1000/(s*(1+0.1*s)*(1+0.001*s));  % Define system in s-domian
% Plot Bode using bode command
bode(G)
```




```
% Visual display of G.M., P.M. , G.C.F AND P.C.F.
margin(G)
```




```
% Getting the numeric Value of G.M., P.M. , G.C.F AND P.C.F.
[gm, pm, wcp, wcg]= margin(G)          % Magnitute in absolute units.
```

```
gm = 1.0100
pm = 0.0584
wcp = 100.0000
wcg = 99.4863
```

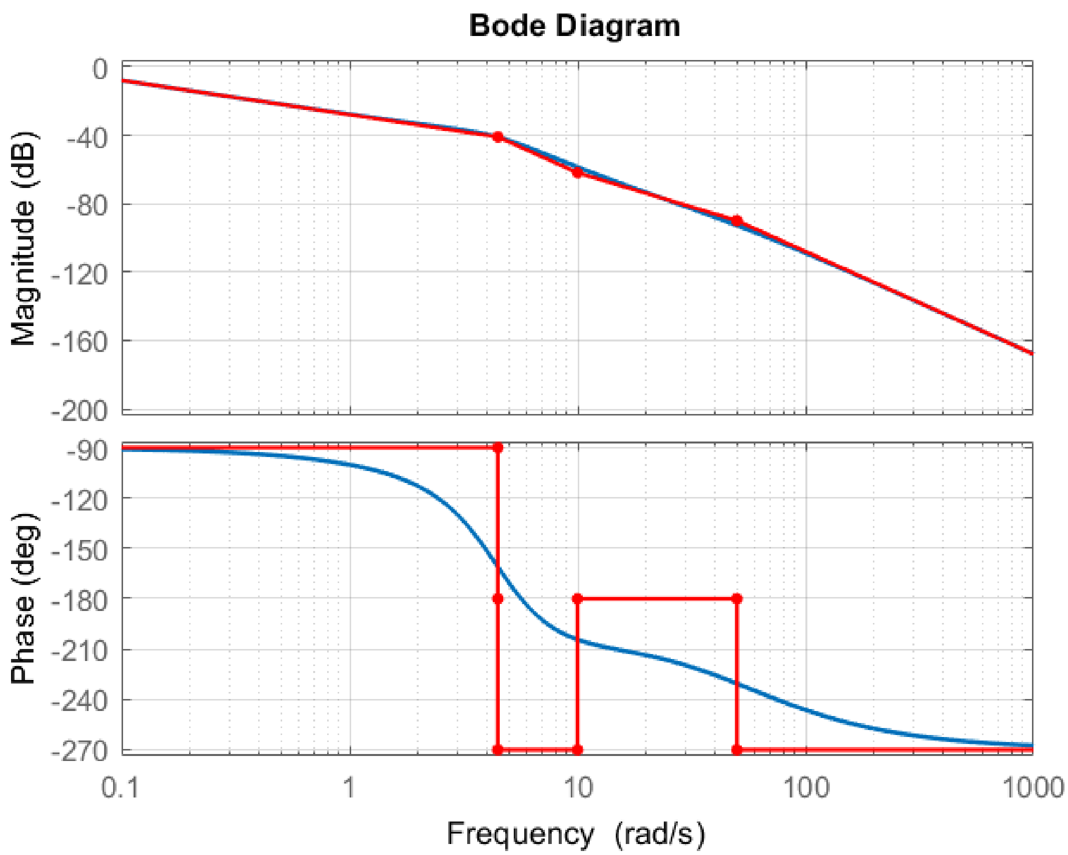
7.5 Asymptotic Bode Plot

```
%define the system
s=tf('s');
G=(4*s+40)/((s^2+5*s+20)*(s^2+50*s))
```

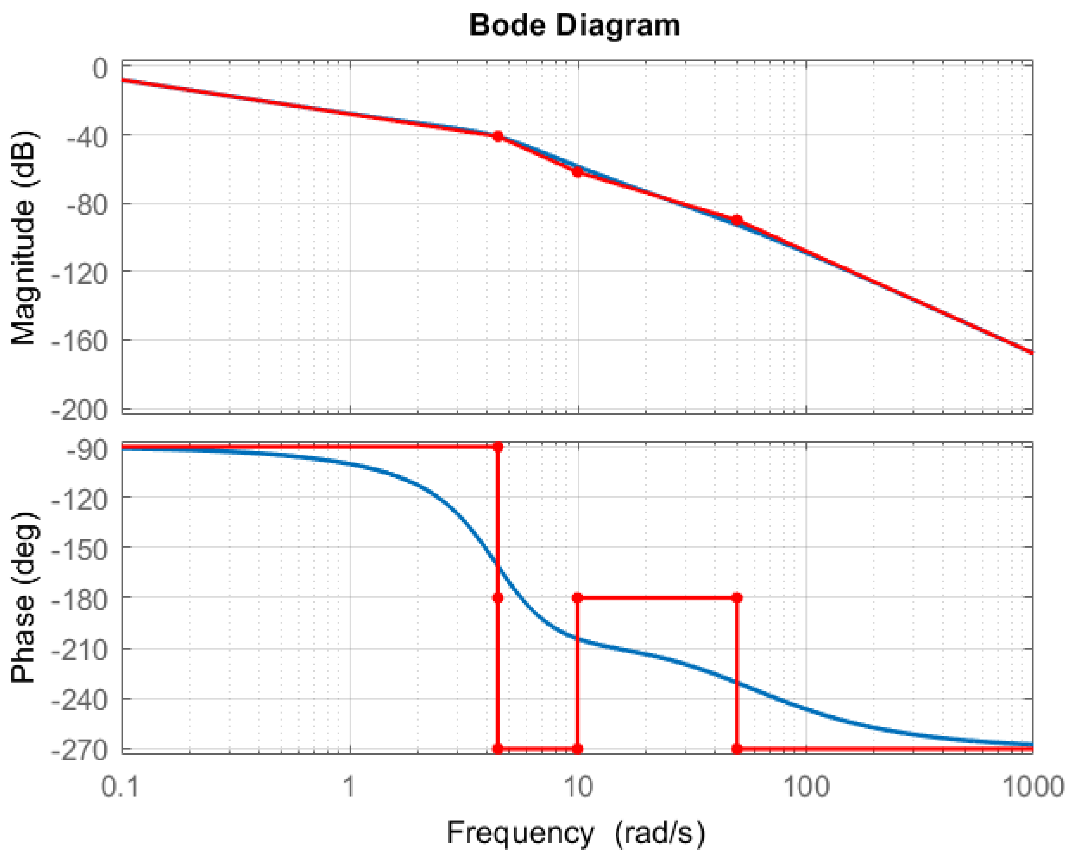
```
G =

             4 s + 40
  -------------------------------
  s^4 + 55 s^3 + 270 s^2 + 1000 s

Continuous-time transfer function.
```

```
%G=1000/(s*(1+0.1*s)*(1+0.001*s));  % Define system in s-domian
% Plot Asymptotic Bode
```

```
asymp_bode(G);
```



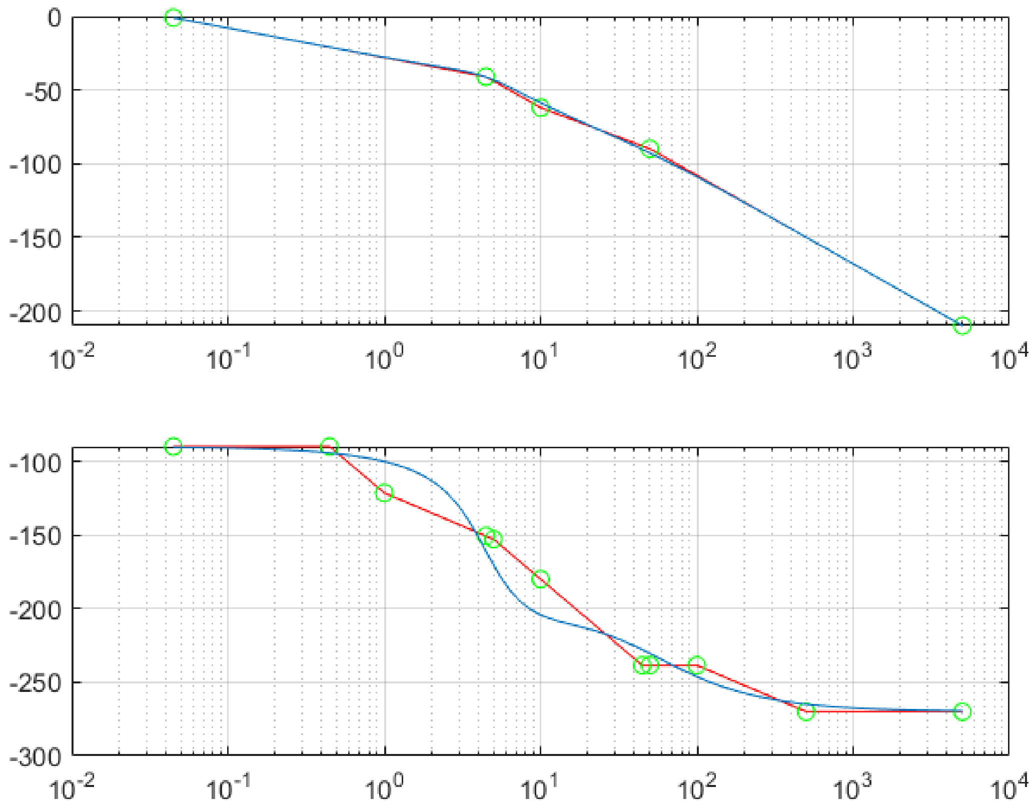

```
asymp_bode(G,0.1,1000);
```




```
%define the system
s=tf('s');
G=(4*s+40)/((s^2+5*s+20)*(s^2+50*s))
```

```
G =

            4 s + 40
  -------------------------------
  s^4 + 55 s^3 + 270 s^2 + 1000 s

Continuous-time transfer function.
```

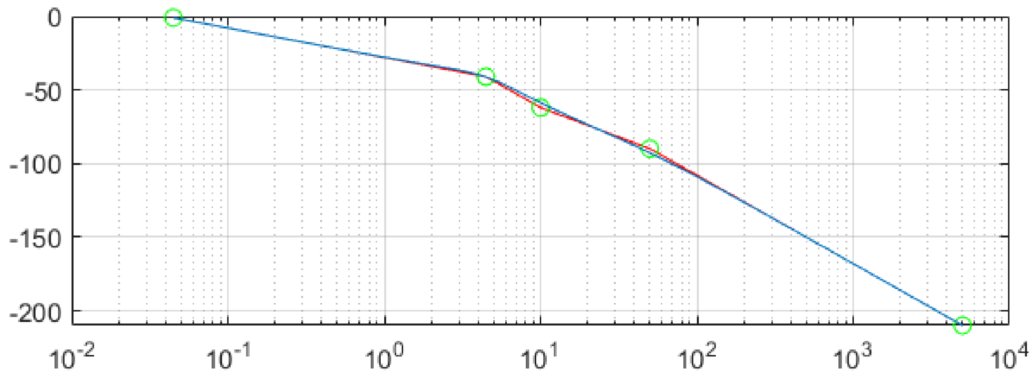
```
%G=1000/(s*(1+0.1*s)*(1+0.001*s));  % Define system in s-domian
% Plot Asymptotic Bode
asymp_bode_1(G);
```

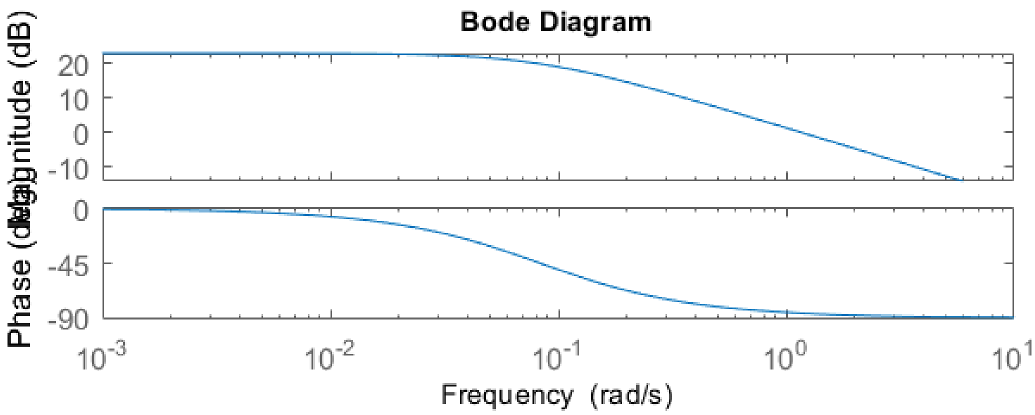



```
ii =

  0×1 empty double column vector


jj =

  0×1 empty double column vector
```

7.6 Effect of Gain and Time Constant on Bode Plot

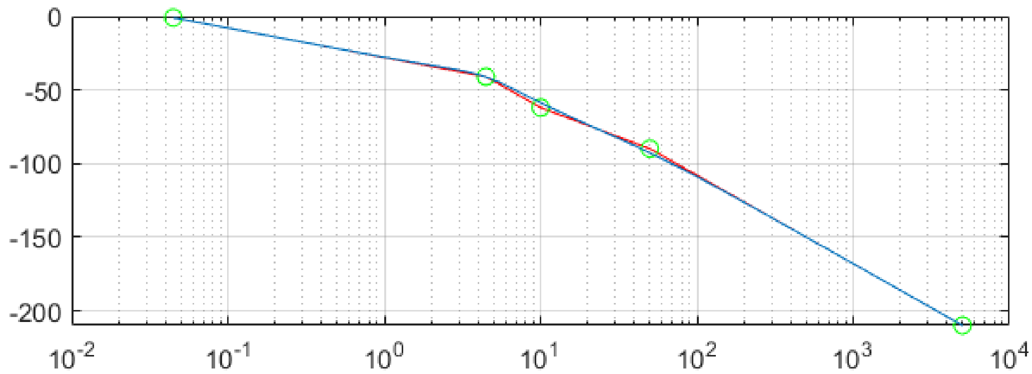
```
%define the system
s=tf('s');
K=14; % Chnage only in magnitute plot[Increase in Value]
T=12; % Change only in Phase [Cauding a time delay]
G=K/(1+T*s);
bode(G);
hold on
```

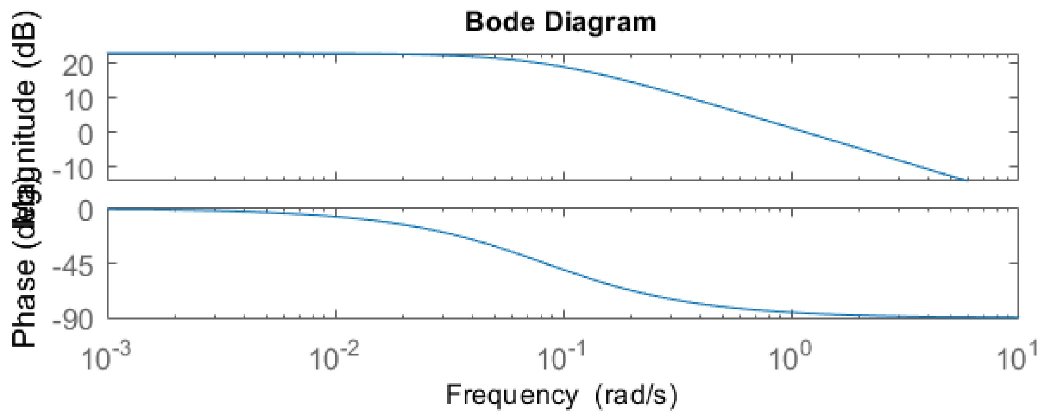




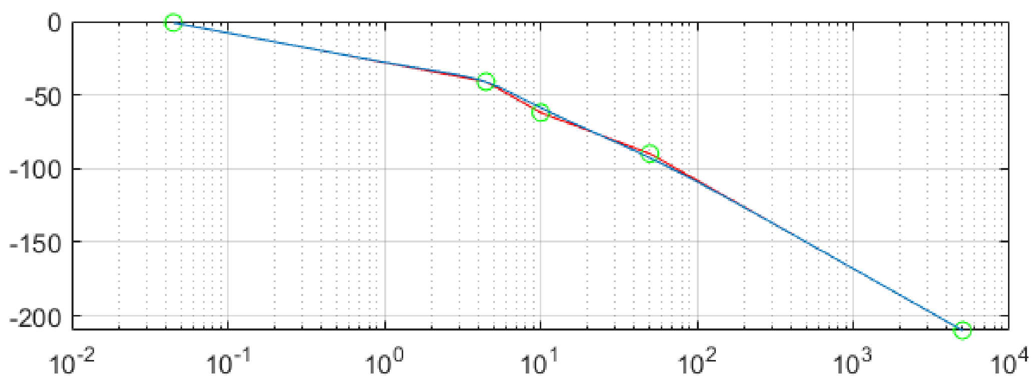
7.7 Polar Plot

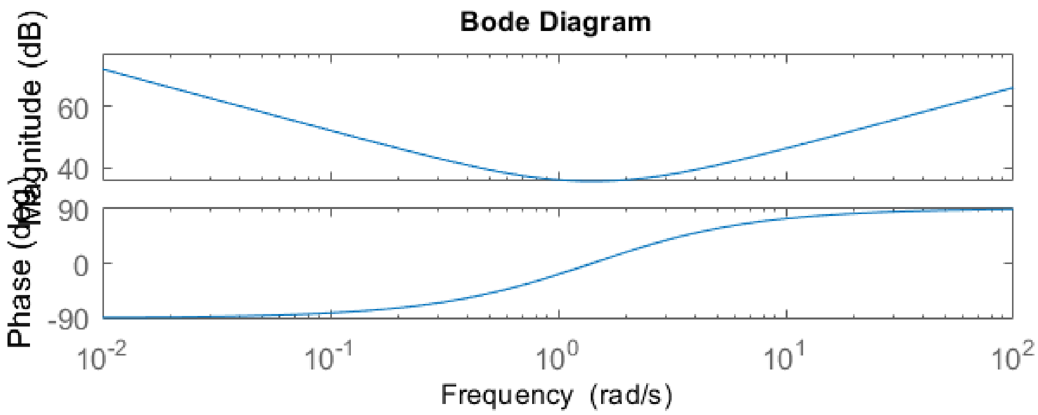
```
hold off
```



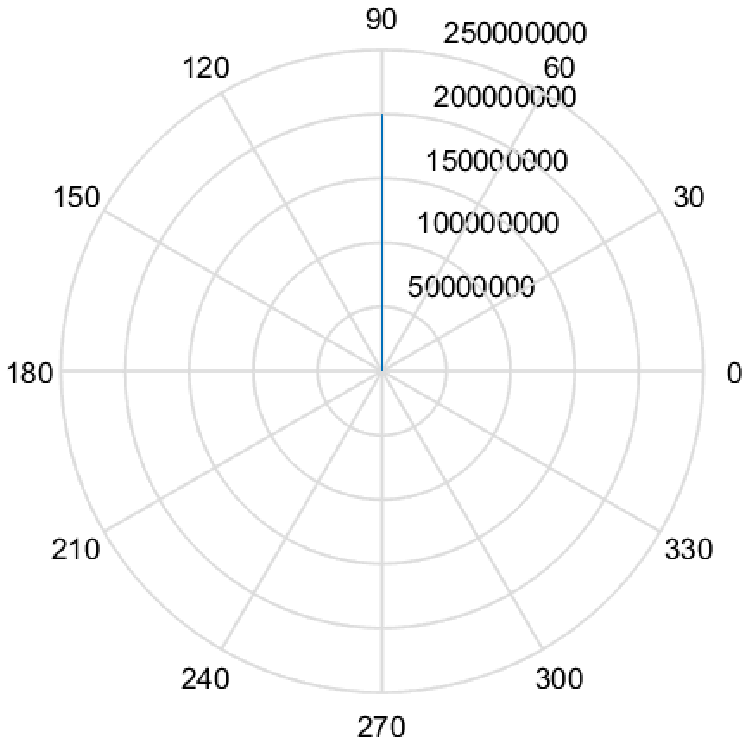



```
s=tf('s');
G=20/s*(1+s)*(s+2);
bode(G);
```



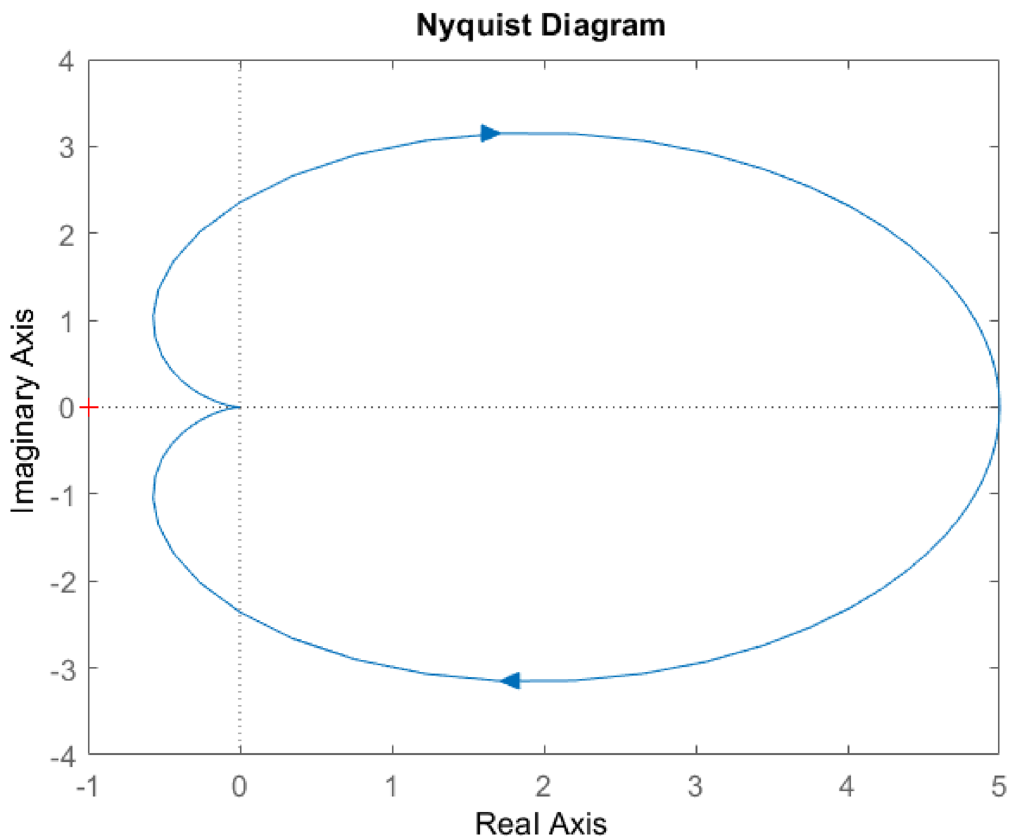



```
w=logspace(-3,7,1000000);
[mag,phase]=bode(G,w);          % Obtaining Magnitute and Phase at w
phase=phase(1,:);
mag=mag(1,:);
figure;
polar(phase*pi/180,mag);
```



7.8 Nyquist Plot

```
s=tf('s');
G=90/((s+3)*(s+6));
nyquist(G)
```



References

1. Mathworks.inc
2. Nise, Norman S. "Control system engineering, John Wiley & Sons." *Inc, New York*(2011).
3. https://ctms.engin.umich.edu/CTMS/index.php?aux=Home
4. Bakshi, Uday A., and Varsha U. Bakshi. *Control system engineering*. Technical Publications, 2020.