Compensation Design

Control system Engineering Experiment:5

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```
clc,clear,clf
s=tf('s');
```

This is your system's open loop transfer function. Replace as per your system design.

$$G(s) = \frac{1}{(2s+1)}$$

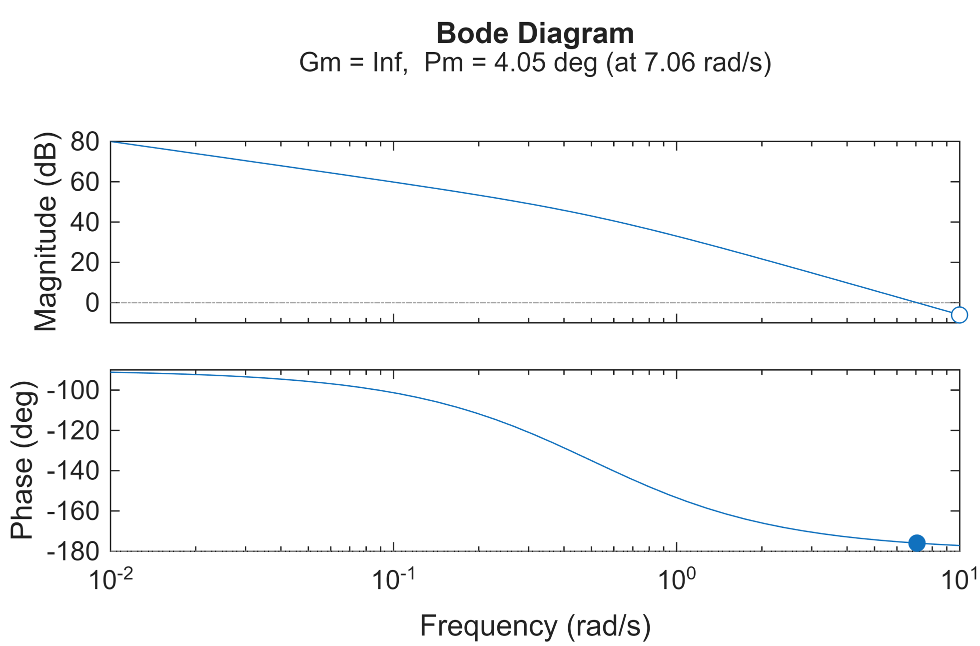
```
G= 1/(2*s+1);
```

Design the K to sarisfy the stready state error requirements and add integrator to ensure zero steady state error. Reduce the gain if compensator is not able to acheive the desired phase margin. In some case a compensator may not be sufficient to achive the desired phase margin, in that case both lead and lag compensator will be required.

```
K=100;
G=K*G*(1/s);
```

Find system margins without compensator,

```
margin(G)
```




```
% Display the gain and phase margins
[Gm, Pm, Wpc, Wgc] = margin(G);
fprintf('Gain Margin: %.2f dB at Frequency: %.2f rad/s\n', db(Gm), Wpc);
```

```
Gain Margin: Inf dB at Frequency: Inf rad/s
```

```
fprintf('Phase Margin: %.2f degrees at Frequency: %.2f rad/s\n', Pm, Wgc);
```

```
Phase Margin: 4.05 degrees at Frequency: 7.06 rad/s
```

```
i=1;
for phi_d = [30,40,50,55,60]
    phi_di(i,:)=phi_d;
    phi_m(i,:)=phi_d-Pm+2;
    alpha(i,:) = (1-sind(phi_m(i,:)))/(1+sind(phi_m(i,:)));
```

Automatic $\omega_d$calculation

```
    alpha_attenuation = 10*log10(alpha(i,:));
    [mag,phase,wout] = bode (G,1e-2:0.01:Wgc*10);
    mag_db=mag2db(mag);
    [~,index] = min(abs(mag_db-alpha_attenuation));
    omega = wout(index);
```

Claculate the compensator time constat to place the additional phase at ω_d frequency.

$$\tau = \frac{1}{\omega_d \sqrt{\alpha}}$$

```
    tau(i,:) = 1/(omega*sqrt(alpha(i,:)));
    C= (1+tau(i,:)*s)/(1+alpha(i,:)*tau(i,:)*s);
    figure(1)
    margin(G*C)
    hold on
```

The frequency response of the Designed Compensator

```
    figure(2)
    bode(C)
    hold on
    [gm(i,:),pm(i,:)] = margin(G*C);
    fprintf("Gain Margin = %0.2f, and Phase Margin = %0.2f \n",
[db(gm(i,:)),pm(i,:)])
```

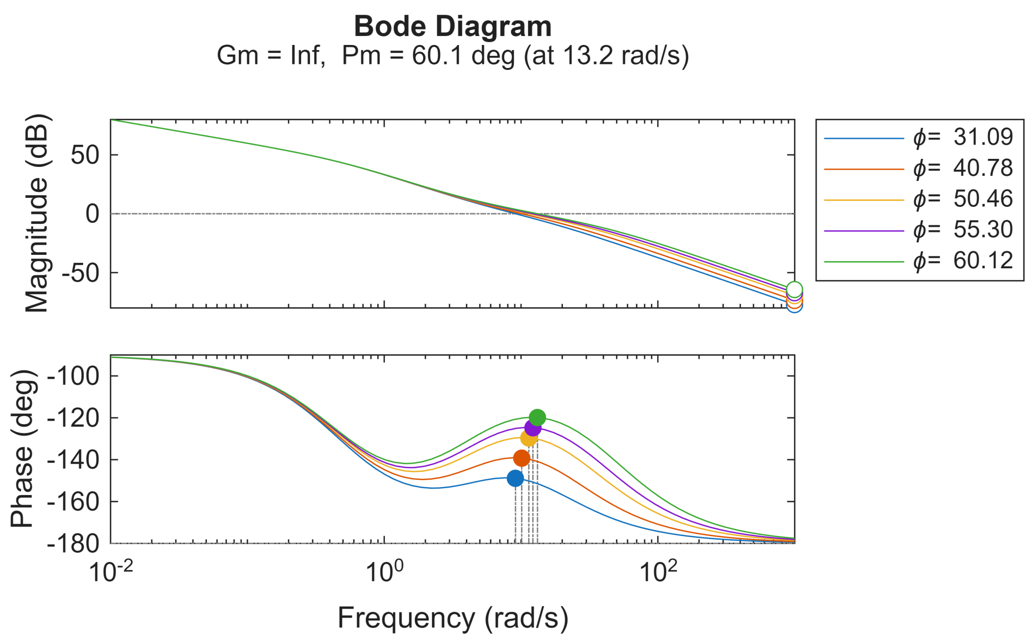
Step response of uncompensated closed loop system and compensated closed loop system with the desired phase margins.

```
    figure(3)
    subplot(2,1,1)
    [y,t]=step(feedback(G*C,1),3);
    plot(t,y)
    hold on
    subplot(2,1,2)
    plot(t,1-y)
    hold on
```

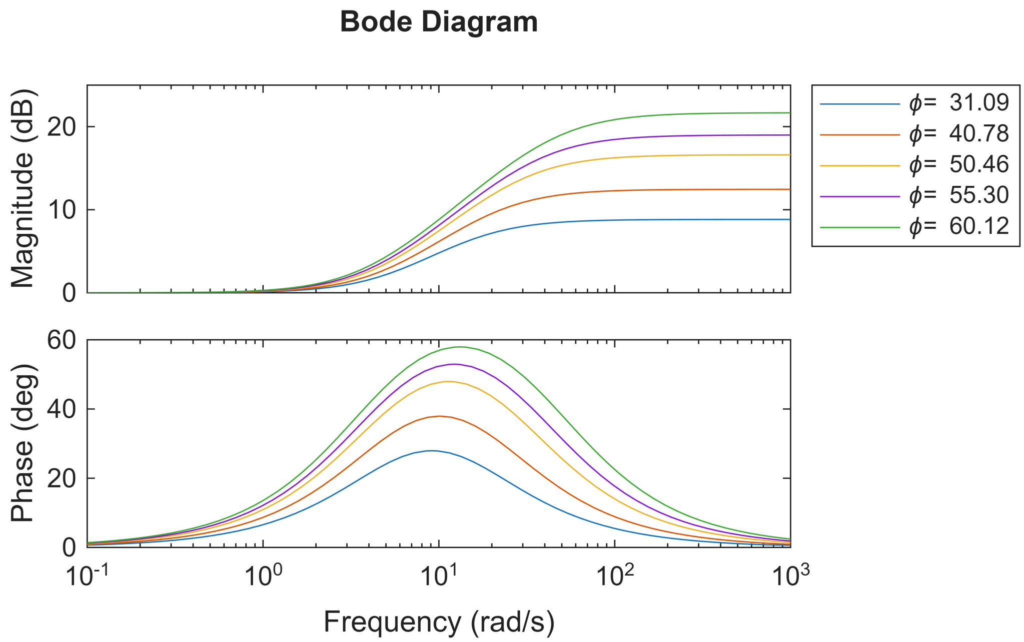
```
    i=i+1;
end
```

```
Gain Margin = Inf, and Phase Margin = 31.09
Gain Margin = Inf, and Phase Margin = 40.78
Gain Margin = Inf, and Phase Margin = 50.46
Gain Margin = Inf, and Phase Margin = 55.30
Gain Margin = Inf, and Phase Margin = 60.12
```

```
legendLabels = arrayfun(@(x) sprintf('\\phi= %.2f', x), pm, 'UniformOutput', false);
[y,t]=step(feedback(G,1),3);
figure(1),legend(legendLabels,Location="bestoutside");
```

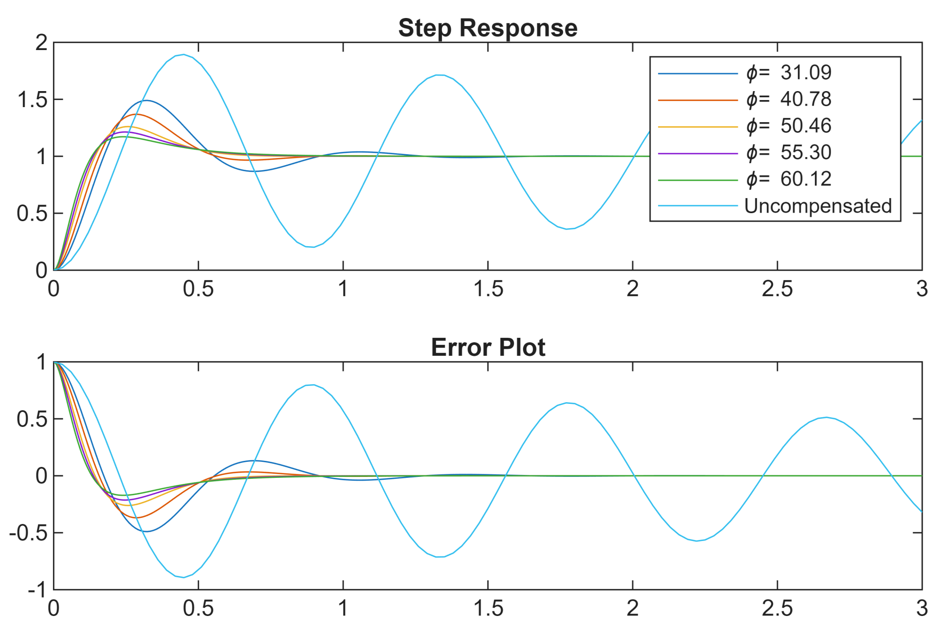



```
figure(2),legend(legendLabels,Location="bestoutside");
```




```
figure(3),subplot(2,1,1), plot(t,y), title("Step Response")
figure(3),subplot(2,1,2), plot(t,1-y),title("Error Plot")
figure(3),subplot(2,1,1)
legendLabels{end+1}='Uncompensated';
legend(legendLabels,Location="northeast")

hold off
```




```
PM_uncomensated = ones(size(phi_di))*Pm;
tab=table(phi_di,PM_uncomensated,pm,alpha,tau, ...
```

```
    'VariableNames',["PM (Desired)","PM (Actual)", 'PM (Compensated)',
"alpha","tau"])
```

tab = 5×5 table

	PM (Desired)	PM (Actual)	PM (Compensated)	alpha	tau
1	30	4.0498	31.0913	0.3617	0.1825
2	40	4.0498	40.7802	0.2384	0.2026
3	50	4.0498	50.4616	0.1477	0.2282
4	55	4.0498	55.2950	0.1123	0.2444
5	60	4.0498	60.1213	0.0825	0.2640