EE 208
Control Engineering Lab

Experiment-1: Dynamic response of transfer functions on MATLAB platform.

Group Number- 20

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OBJECTIVE: -

To analyse and discuss the dynamic response of a given linear analog system in terms of different performance measures.

Given: -

A second order analog OLTF of an oven temperature system,

OLTF: $G_{OL}(s) = \frac{k}{s^2+3s+10}$

A given PD controller to be considered in a) Cascade and b) Feedback

PD control: $G_C(s) = 80(s+5)$

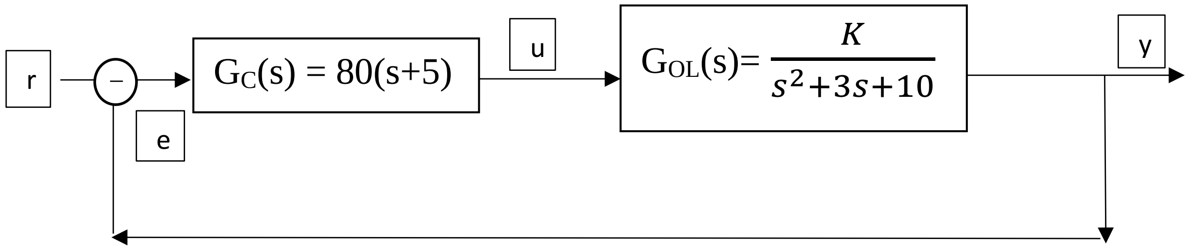


Fig.-1: Block Diagram for Cascaded System

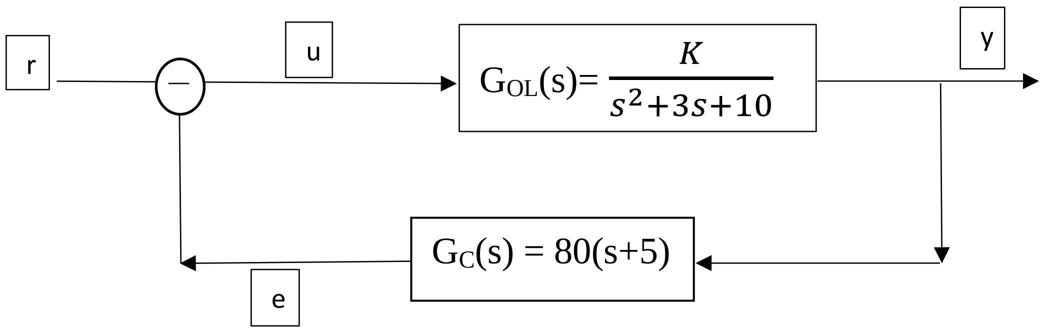


Fig.-2: Block Diagram for Feedback System

SYSTEM MODELLING: -

To analyze the system in terms of step response we first have to model the closed loop transfer function for both the cascaded and feedback configuration.

a) Cascade-

Closed loop transfer function (CLTF) for the system

$$H_c(s) = \frac{80ks+400k}{s^2+(80k+3)s+10+400k}$$

```
%cascade modelling of system
s=tf('s');
k=1;                    %open loop gain k
Gc=tf([80,80*5],1);
Gol=tf(k,[1,3,10]);
Hc=feedback(Gc*Gol,1);  %cascaded CLTF
```

Script-1: Script for generating transfer function for cascaded system

b) Feedback-

Closed loop transfer function (CLTF) for the system

$$H_f(s) = \frac{k}{s^2+(80k+3)s+10+400k}$$

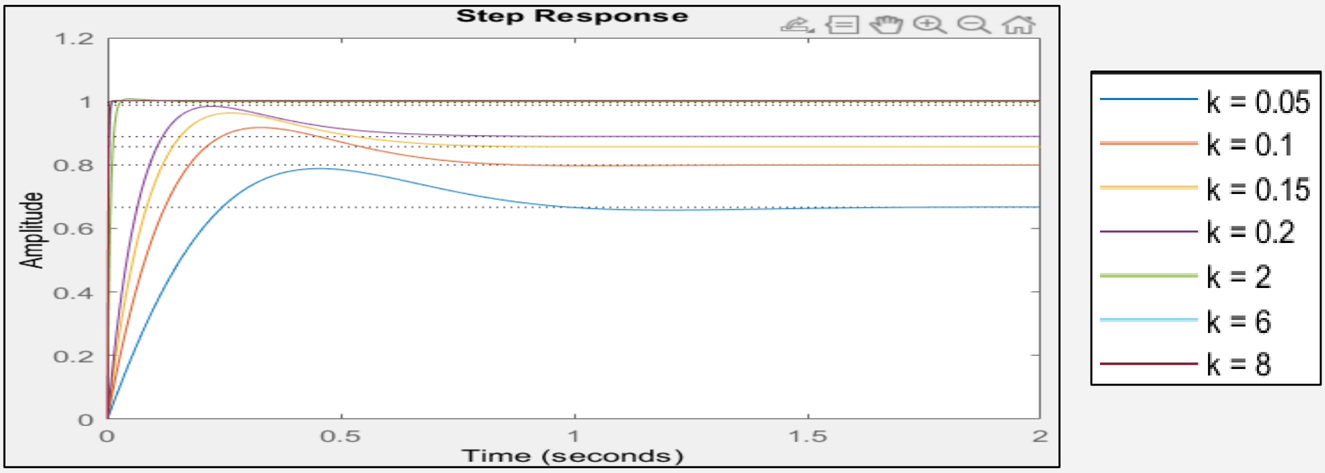
```
%feedback modelling of system
s=tf('s');
k=1;                    %open loop gain k
Gc=tf([80,80*5],1);
Gol=tf(k,[1,3,10]);
Hf= feedback(Gol,Gc);   %feedback CLTF
```

Script-2: Script for generating transfer function for feedback system

OBSERVATION: -

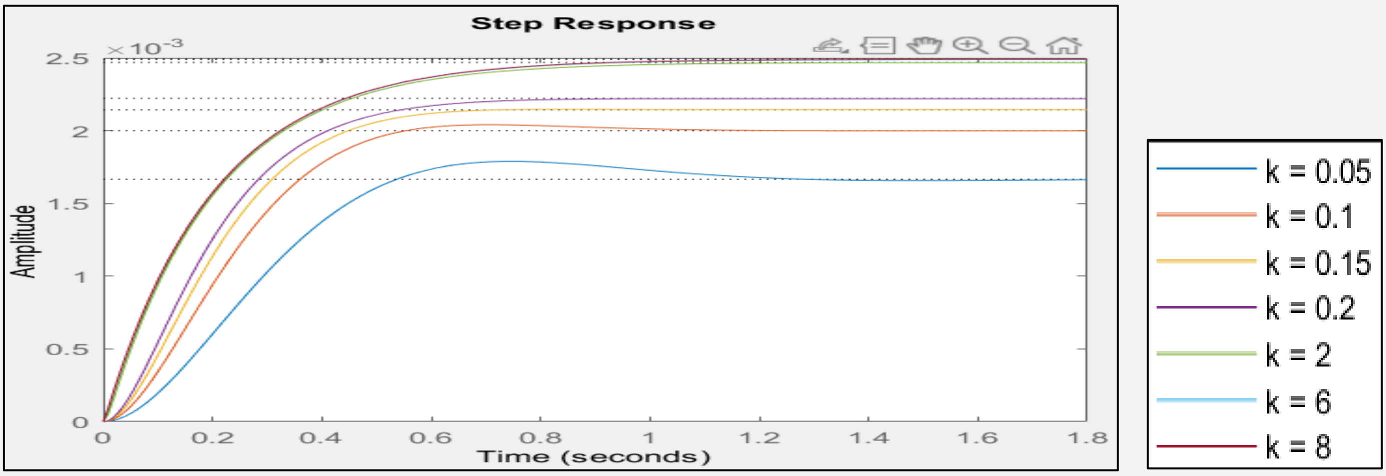
1) Step Response

a) Step Response of the system for cascaded system



Graph-1: Step Response for Cascaded System

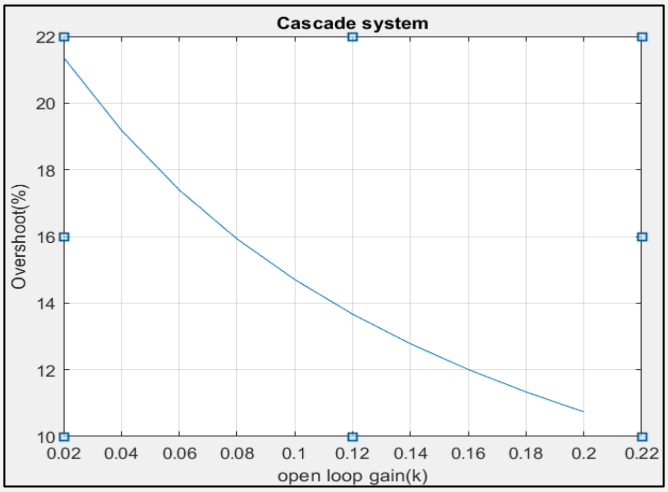
b) Step Response of the system for feedback system

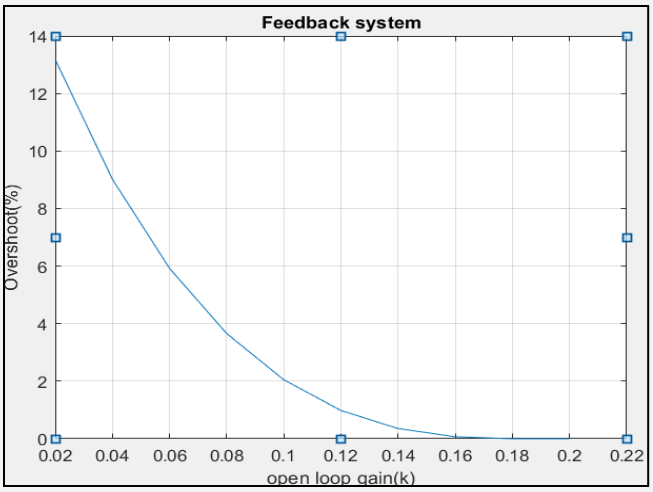


Graph-2: Step Response for Feedback System

- For both the systems as k becomes large the response approaches a steady state value as open loop gain tends to **infinity**.
- For low values of k the system response consists of decaying oscillation.
- The oscillatory behaviour also **decreases** with increasing value of open loop gain.

2) Percentage Overshoot



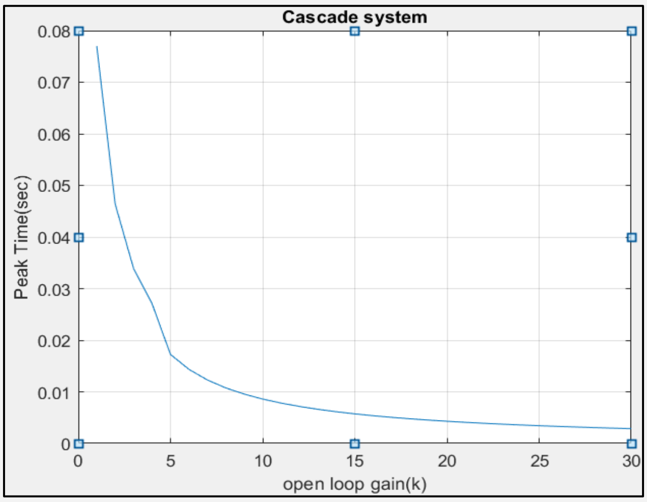


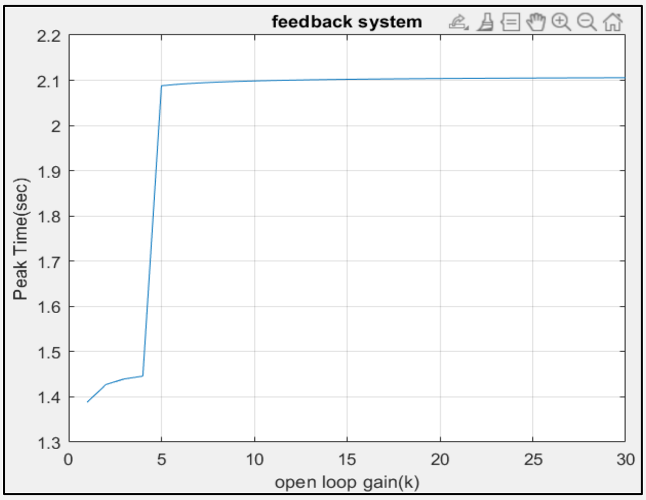
Graph-3 Percentage overshoot for Cascaded system **Graph-4 Percentage overshoot for feedback system**

- The overshoot is observed to decrease for both the systems with **increase** in open loop gain.
- It can be observed that feedback system overshoot is **always less** than cascaded system.
- The percentage overshoot in both systems **tends to zero** as open loop gain tends to infinity.
- For the better performance of system, percentage overshoot of the system should be low, hence cascaded system performs better.

S. No.	Open Loop Gain(K)	Overshoot	
		Cascade	**Feedback**
1)	0.02	21.3706033145833	13.1760078639278
2)	0.04	19.1883536156366	9.01973991053391
3)	0.06	17.3963728550275	5.91987727108341
4)	0.08	15.9249614499594	3.65469284873037
5)	0.10	14.7047557835246	2.04791273288842
6)	0.12	13.6685365284175	0.979709167402465
7)	0.14	12.7801554156997	0.351988784837776
8)	0.16	12.0083047331154	0.0682160095424544
9)	0.18	11.334870580954370	0
10)	0.20	10.7355134095167	0

3) Peak Time





Graph-5: Peak time for Cascaded System

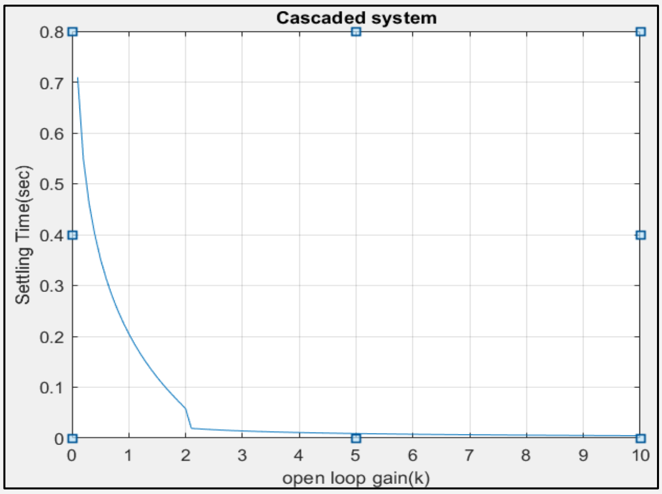
Graph-6 Peak Time for Feedback System

- It could be inferred from the graph that for a cascaded system with increase in open loop gain the peak time **decreases** i.e., the system **responsiveness increases**.
- Whereas for the feedback configuration there is an optimal value of k where the peak time is **minimum** and with further increase of open loop gain the peak time increases thus making the **system slower**.
- **System performance is better for low peak time.** This trait is more observed in case of Cascaded System with increase in open loop gain.

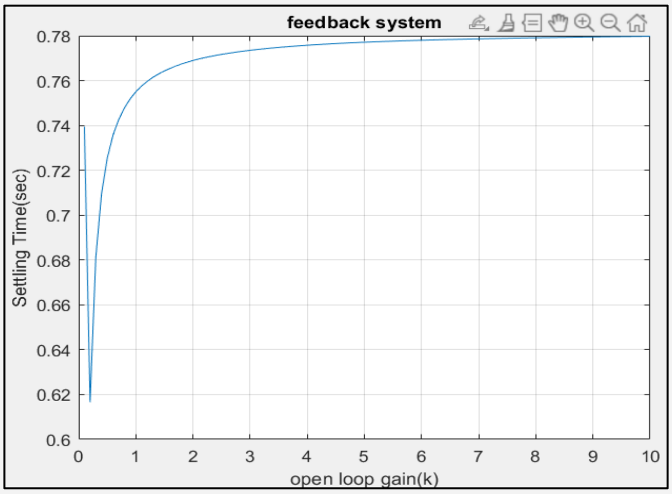
S. No.	Open Loop Gain(K)	Peak Time	
		Cascade	**Feedback**
1)	1	0.0770244053553725	1.38809642106399
2)	10	0.00781535606808554	2.09954777165913
3)	20	0.00408924461420935	2.10413709728574
4)	30	0.00276905809988660	2.10576193011324
5)	40	0.00209326307756054	2.10659342961559
6)	50	0.00168261692972779	2.10709860941057
7)	60	0.00140666448348234	2.10743805408534

8)	70	0.00120847267304701	2.10768182980109
9)	80	0.00105923230162006	2.10786538600300
10)	90	0.000942801067563747	2.10800858349922

4)Settling Time



Graph-7: Settling time for cascaded system

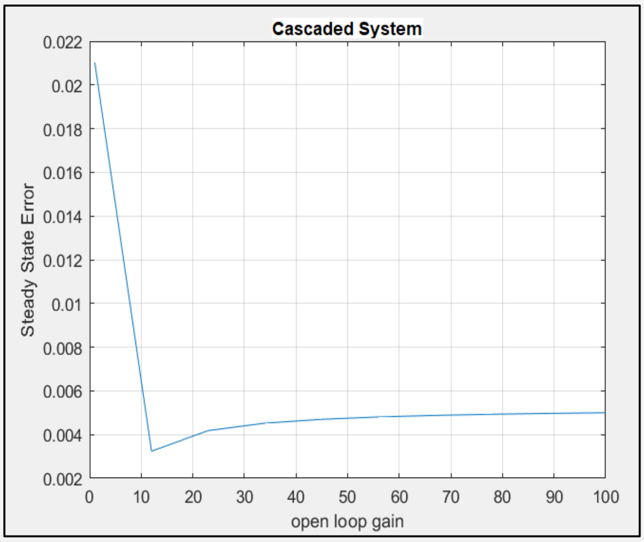


Graph-8: Settling time for Feedback System

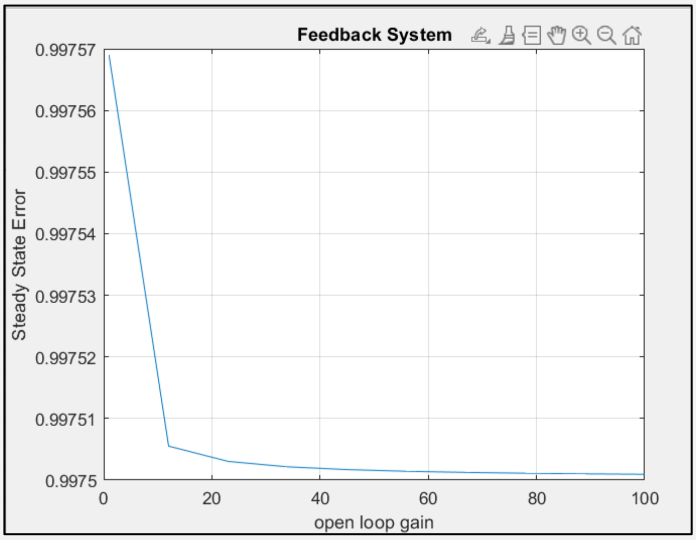
- For both the configurations the settling time **initially decreases** but for the feedback system it eventually **settles** down to a constant value greater than the cascaded system.
- For the feedback system the settling time is observed to **increase** after achieving the minima.
- Whereas the settling time for the cascaded system seemed to **fall gradually**.

S. No.	Open Loop Gain(K)	Settling Time	
		Cascade	Feedback
1)	0.1	0.709345006397041	0.739442899176036
2)	0.2	0.549221290276668	0.616633958517330
3)	0.3	0.462161893500446	0.681236059148698
4)	0.4	0.400769909634611	0.709562631450748
5)	0.5	0.353078177381940	0.725376275288126
6)	0.6	0.314082954388157	0.735507602032534
7)	0.7	0.281130950141412	0.742565002745339
8)	0.8	0.252623384452121	0.747784335432663
9)	0.9	0.227518354797539	0.751812876013803
10)	1.0	0.205100526174094	0.754987945018682

5) Steady State Error



Graph- 9: Steady state error for Cascaded System



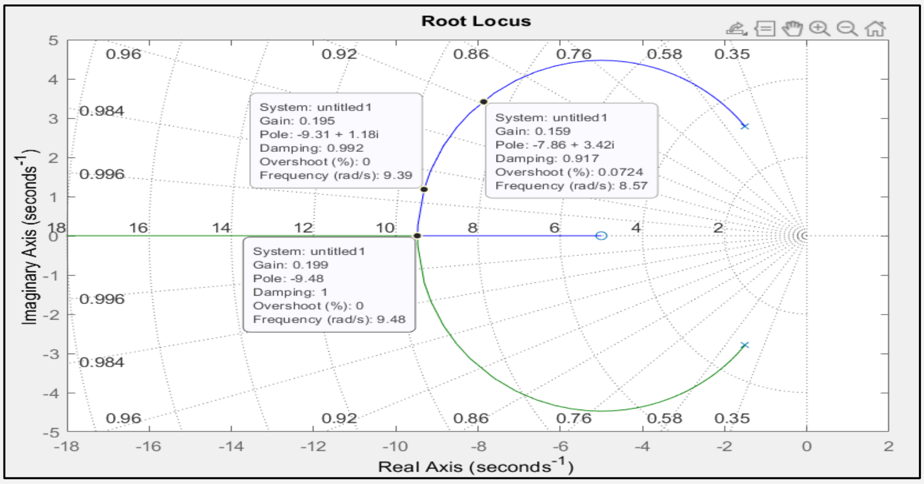
Graph- 10: Steady state error for Feedback System

- We can infer the huge difference in the percentage steady state error on comparing the cascaded and the feedback systems, the value for the steady state error for the feedback system was **very high** as compared with the cascaded system.
- For the cascaded system the **error is quite minimal**. With increase in value of k the steady state **error decreases**.
- For the feedback system it could be seen that steady state error is **unlikely to be eliminated by varying k.**
- For better performance, steady state error should be **low** and clearly the cascaded system performs much better in this case.

S. No.	Open Loop Gain(K)	Steady State Error	
		Cascade	Feedback
1)	10	0.021019705907 41015	0.997568877637305
2)	20	0.00324183874860207	0.997505513237046
3)	30	0.00418486863469103	0.997503029689914
4)	40	0.00452490324945176	0.997502151965221
5)	50	0.00470015388197753	0.997501703112536
6)	60	0.00480703692073281	0.997501430516286
7)	70	0.00487902814235919	0.997501247395924
8)	80	0.00493081534200512	0.997501115908375
9)	90	0.00496985703291175	0.997501016914255
10)	100	0.00500034284631878	0.997500939693408

ANALYSIS: -

For the above two configurations, the step response is of similar type as the CLTF of both the equations have same characteristic equation (i.e., similar root loci as well).



Graph- 11: Root locus

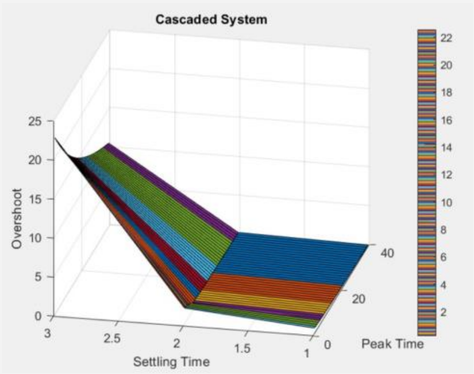
In either of the configuration the closed loop loci are similar but the **difference would be in the zeros** of the resulting system which would subsequently **affect the step response** as well. With increase in open loop gain (k) the damping ratio (ζ) also **increases** which will vary the system from **underdamped** to **damped** and eventually the system becomes **overdamped**.

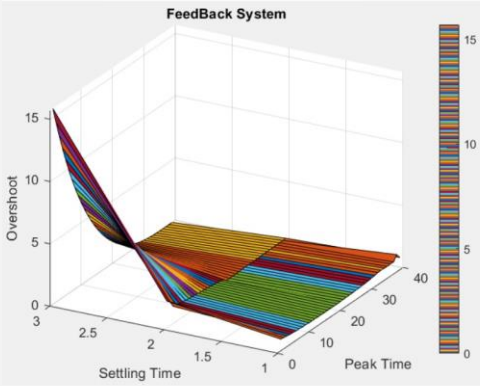
0<k<0.199 – underdamped
k=0.199
k>0.199 – Overdamped
This can be verified from the Graph- 11

- First of all, **both the systems are stable** for all positive values of k as the complete root locus lie in on the **negative side of real axis**.
- We can see that for **lower values** of k the step response obtained is of a **second order system**. As the value of k **increases**, one of the closed loop poles started to **move away from the imaginary axis (redundant pole)**. Therefore, for **high values of k** the contribution from **redundant pole is negligible** and the step response will be similar to a **first order system**.
- In General, the **addition of zero** on left hand plane **increases the overshoot** and **decreases the peak time and rise time and the settling time is not much affected.**

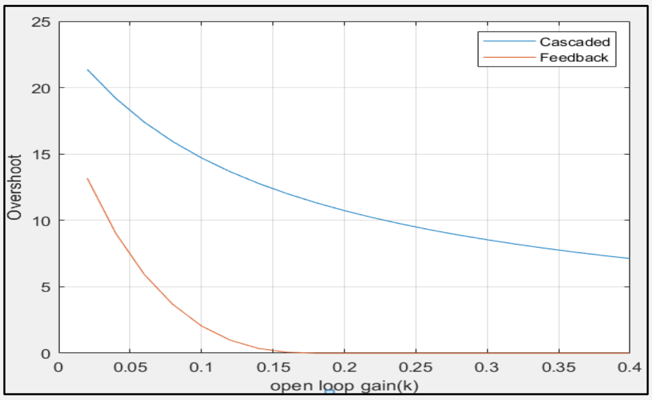
  Therefore, the **cascaded system** has always **high Percentage Overshoot** then feedback system for a given value of k.

  Further, the Percentage Overshoot of feedback system **drops to zero** for K beyond 0.199 (system becomes overdamped), but for Cascaded one it is **non-zero** for K=0.199 due to the additional zero at s = -5.





Graph-12: Comparison for Cascaded System **Graph-13: Comparison for Feedback System**



Graph- 14: Comparison of peak overshoot

- In Cascaded System,

$$\lim_{k\to\infty} Hc(s) = \lim_{k\to\infty} \frac{80k(s+5)}{s^2+(80k+3)s+10+400k}$$

$$\lim_{k\to\infty} Hc(s) = \lim_{k\to\infty} \frac{80(s+5)}{80(s+5)}$$

$$\lim_{k\to\infty} Hc(s) = 1 = \frac{Y(s)}{U(s)}$$

- In Feedback System,

$$\lim_{k\to\infty} Hc(s) = \frac{k}{s^2+(80k+3)s+10+400k}$$

$$\lim_{k\to\infty} Hc(s) = \frac{1}{80(s+5)}$$

From above, we can see that in case of Cascaded system, due to **cancellation of pole and zero** the response of the system approaches to Step function and **Steady State Error** also **vanishes** with **increasing** value of k. However, this cancellation doesn't occur in case of Feedback System (no zero is present) and we get a **significant steady state error** for all K.

<u>CONCLUSION: -</u>

The given analog system was thoroughly analysed with respect to its performance measures.

It can be concluded that the performance of cascaded is better as compared to feedback system. It achieves suitable parameter values (i.e., lesser peak time, comparable settling time and minimal steady state error).

SCRIPTS: -

```
Gc=tf([80,80*5],1);
k=.1:.1:10;                                     %open loop gain k
hold off;
for i=1:100
    Gol=tf(k(1,i),[1,3,10]);

    HcC(1,i)=feedback(Gol*Gc,1);            %cascade
    HcF(1,i)=feedback(Gol,Gc);              %feedback

    b=stepinfo(HcC(1,i));
    c=stepinfo(HcF(1,i));

    dataC(1,i)=b.SettlingTime();           %data cascaded
    dataF(1,i)=c.SettlingTime();           %data feedback

    step(HcC(1,i));
    hold on
    step(HcF(1,i));
    hold on
end
```

Script- 3: Script for analyzing settling time for varying k

```
Gc=tf([80,80*5],1);
k=.1:.1:10;                                     %open loop gain k
hold off;
for i=1:100
    Gol=tf(k(1,i),[1,3,10]);

    HcC(1,i)=feedback(Gol*Gc,1);            %cascade
    HcF(1,i)=feedback(Gol,Gc);              %feedback

    b=stepinfo(HcC(1,i));
    c=stepinfo(HcF(1,i));



   [y,t]=step(HcC(1,i));
    [Y,T]=step(HcF(1,i));

    ssc(1,i)=abs(1-y(end));                 %steady state error cascaded
    ssf(1,i)=abs(1-Y(end));                 %steady state error feedback
end
```

Script- 4: Script for analyzing steady state error for varying k

```
hold off;
plot(k,dataC);
hold on;
%plot(k,dataF);
hold on;
title('Cascaded system');
xlabel('open loop gain(k)');
ylabel('Settling Time(sec)');
```

Script- 5: Script for plotting and analyzing different parameters

Thank You!