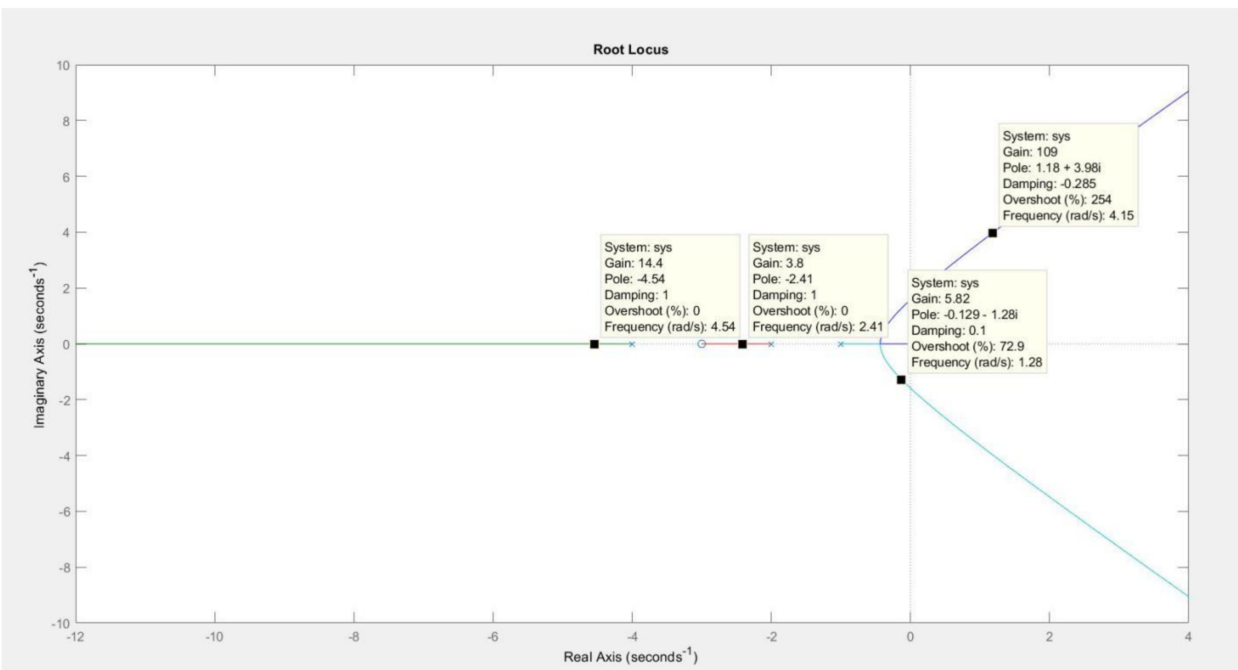
Bangladesh University of Business & Technology
Control System Lab
EEE 402

Experiment No: 07
Experiment Name: Design via root locus.

In the last lab, you were introduced with the root-locus technique. Now we'll design a control system exploiting that technique.

$$G(s) = \frac{s+3}{s(s+1)(s+2)(s+4)}$$



Now let's say we want to design a system with overshoot less than 10%

Can we design such a system?

- The relation between %OS and damping ratio is –

$$\zeta = \sqrt{\frac{\ln(OS)^2}{\pi^2 + \ln(OS)^2}}$$

Then the design parameter can be calculated as -

$$\zeta = 0.59$$

Now let's say we want to design a system with rise time Tr less than 1s.

- The relation between rise time and ω_n is –

$$\omega_n \geq \frac{1.8}{Tr}$$

Then design parameter can be calculated as --

$$\omega_n \geq 1.8$$

Now, we can include this in Matlab this way –

```
num= [1,3];

den= conv(conv([1,0],[1,1]),conv([1,2],[1,4]));

g=tf(num,den);

rlocus(num,den)

zeta=0.59;

wn= 1.8;

sgrid(zeta,wn)

[k,poles]=rlocfind(num,den)

[nc,dc]=cloop(k*num,den)

z=tf(nc,dc)

step(z)
```

- You'll find two straight lines corresponding to the value of ζ. Any poles located in the region bounded by these two lines will result in ζ value of greater than 0.59. Which will make the %OS less than 10%.
- You'll find a semi-circle with a radius equal to ω_n. So any point outside the circle will satisfy our condition of rise time < 1s.
- So, in order to design our system, we must satisfy the above mentioned criteria.

- For only one design parameter, use 0 in the sgrid function i.e.

  sgrid(zeta,0)

Using the 'rlocfind' function, you can select any point in the root locus and see the response.

Try some points and see whether you can satisfy the design criteria.

Exercise:

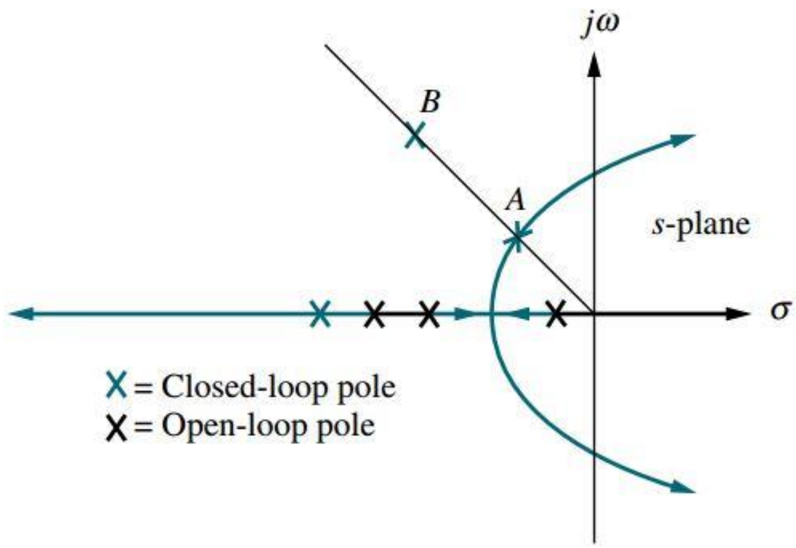
$$G(s) = \frac{K(s+1.5)}{s(s+1)(s+10)}$$

Design the system for OS < 10% and rise time < 2s.

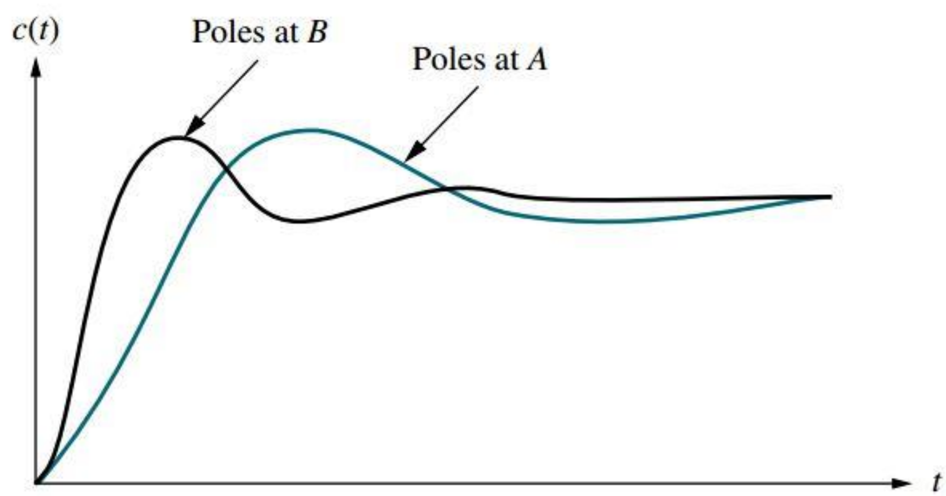
- Now, let's say we want faster response i.e. smaller settling time.

$$T_s = \frac{4}{\zeta\ \omega_n}$$

  then we need larger $\zeta\omega_n = \sigma_d$ i.e. we've to go leftwards on the plot.
  if we want this keeping the %OS constant, then we just have to follow the ζ line.



- So, our goal is to speed up the response at A to that of B, without affecting the percent overshoot. This increase in speed cannot be accomplished by a simple gain adjustment, since point B does not lie on the root locus.
- One way to solve this problem is to replace the existing system with a system whose root locus intersects the desired design point, B. Unfortunately, this replacement is expensive and counterproductive.
- Rather than change the existing system, we augment, or compensate, the system with additional poles and zeros, so that the compensated system has a root locus that goes through the desired pole location for some value of gain.

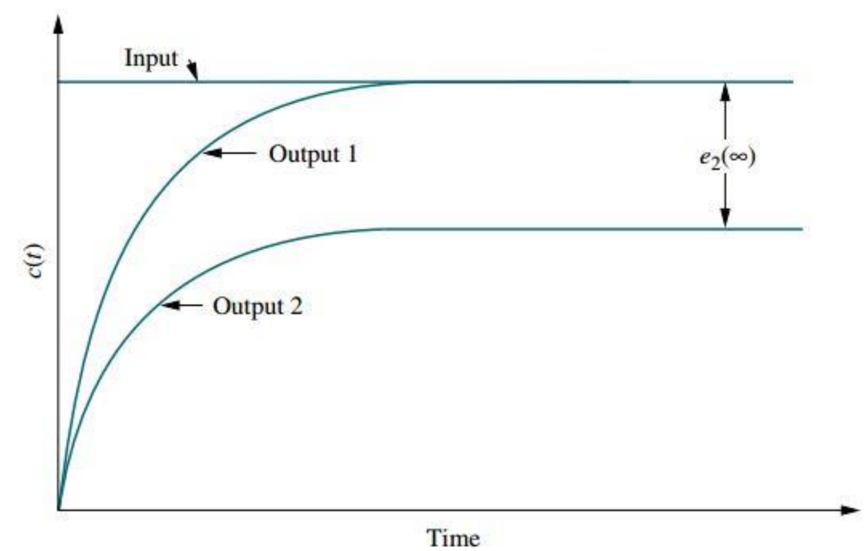


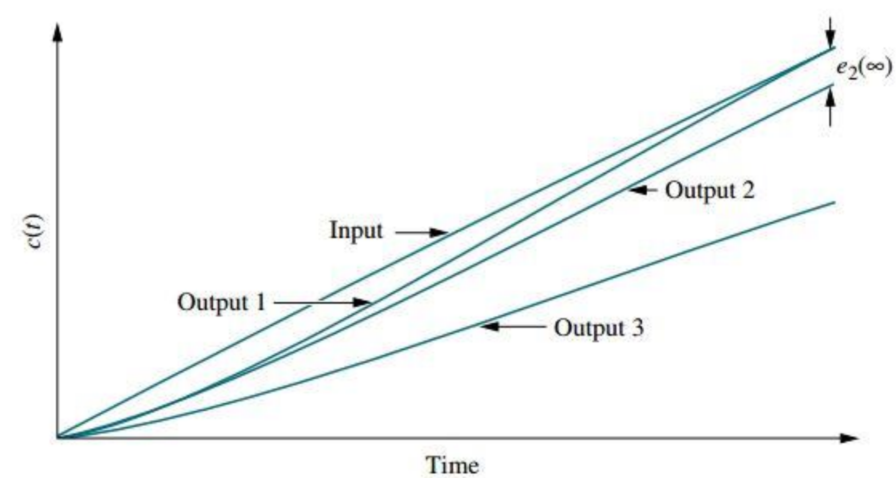
[The design procedure of these kind of compensators will be taught in the class]

Lecturer, EEE, BUBT

Steady-State Error:

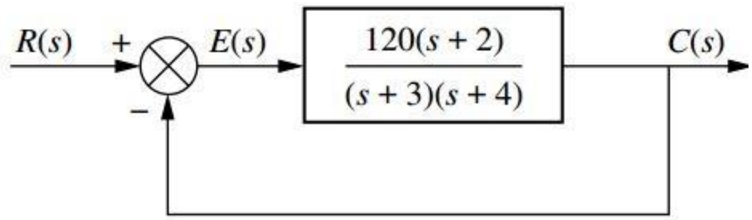
Steady-state error is the difference between the input and the output for a prescribed test input as t tends to infinity.
The test input can be a step function or a ramp function etc.
Error for these type of inputs looks like below --





To evaluate steady-state error from Matlab, 1st plot the step response. Then find out the steady state value. The difference from 1 gives the error.

Exercise: Find out the steady-state error for the system below --



Now, look at your previous design of root-locus and see how gain adjustment affects the ss error.

When the system gain was adjusted to meet the transient response specification, steady-state error performance deteriorated, since both the transient response and the static error constant were related to the gain. The higher the gain, the smaller the steady-state error, but the larger the percent overshoot. On the other hand, reducing gain to reduce overshoot increased the steady-state error.

By using dynamic compensators, compensating networks can be designed that will allow us to meet transient and steady-state error specifications simultaneously.