EE324: CONTROL SYSTEMS LAB
PROBLEM SHEET 6

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Contents

1 Design of Proportional controller

The given open loop transfer function of a system with unity negative feedback is as follows:

$$G(s) = \frac{1}{(s+3)(s+4)(s+12)}$$

On applying a Proportional controller of gain K, the closed loop transfer function is given by,

$$T(s) = \frac{KG(s)}{1+KG(s)}$$

1.1 Problem a

We have to find the gain K such that the steady state error is 0.489. We know that we can find steady state error as,

$$S.S.E = \lim_{s\to 0} \frac{1}{1+KG(s)}$$
$$\implies 0.489 = \frac{1}{1+K*G(0)}$$
$$\implies 0.489 = \frac{1}{1+K*\frac{1}{3*4*12}}$$
$$\implies 0.489 = \frac{1}{1+\frac{K}{144}}$$
$$\implies K = 150.4785$$

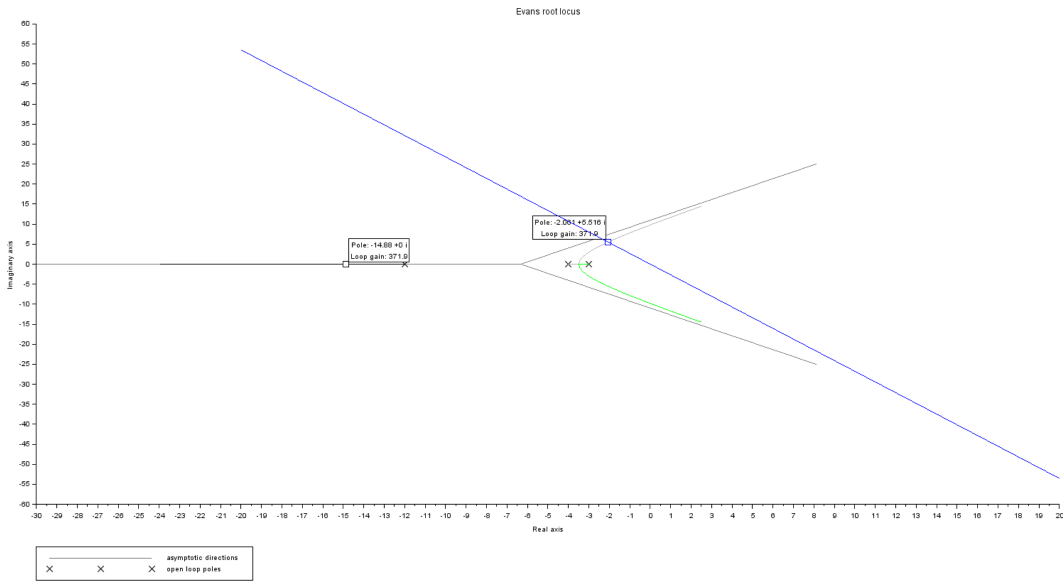
1.2 Problem b

We have to design a Proportional controller for obtaining a damping ratio of 0.35 From the given zeta we can finf the angle theta which the poles of the approximated second order system should make with the negative real axis. Hence, using this theta we plot a line passing through the origin and check for the intersection of the line with the root locus of G(s). We use Scilab for this.

Scilab Code

```
clear
close
clc

s = poly(0,'s');

G = (1)/((s+3)*(s+4)*(s+12));
Glin = syslin('c',G);
evans(Glin,5000);

// Finding theta from the damping ratio

zeta = 0.35;
theta = acos(zeta);
x = -20:0.1:20;
y = -tan(theta)*x;
plot(x, y);
```

Obtained plot



From this plot we can that we have an intersection at pole -2.06 + 5.51 i. The gain K at this value 371.9. Also from the plot we can see that the third root at this value of K is -14.88. We can easily see that this pole is more than 5 times away from the dominant poles and hence our second order approximation of the system is correct.

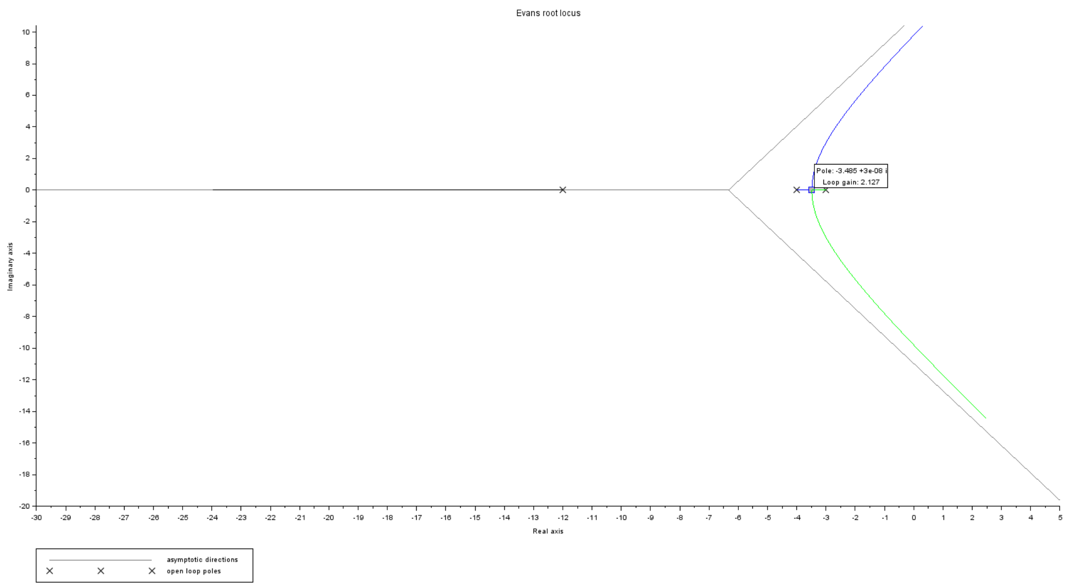
Answer

K = 371.9

1.3 Problem c

We use the root locus plotted in part b to obtain the value of gain at the break away point.

Obtained Plot



Answer

K = 2.127

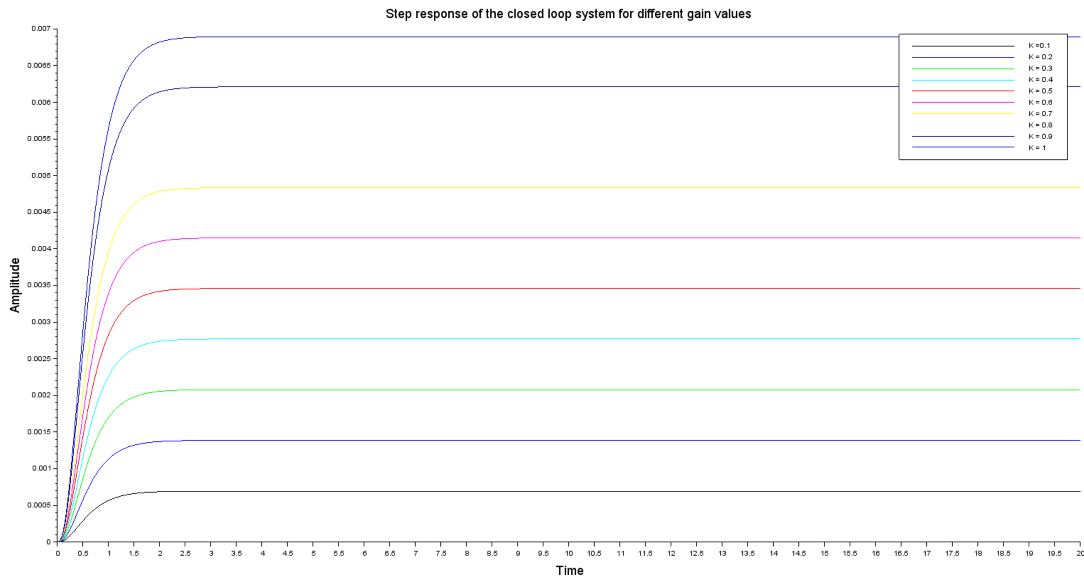
1.4 Problem d

We increase the value of the gain from 0 to 1 in steps of 0.1. The obtained step response is as follows

Scilab Code

```
clear
clc

s = poly(0,'s');
G = 1/((s+3)*(s+4)*(s+12));

for k = 0.1:0.1:1
    T = k*G/(1+ k*G);
    T1 = syslin('c', T);
    t = 0:0.05:20;
    ts1 = csim('step' , t , T1);
    plot2d(t,ts1,style = 11*k);
end
xlabel('Time','fontsize',4)
ylabel('Amplitude','fontsize',4)
legend('K =0.1','K = 0.2','K = 0.3','K = 0.4','K = 0.5','K = 0.6','K = 0.7','K =
    0.8','K = 0.9','K = 1')
title('Step response of the closed loop system for different gain values', '
    fontsize',4)
```

Obtained plot



The response of this system is similar to that of a second order overdamped system. However on increasing the gain the response is moving closer to that of a critically damped system. Hence, two of the closed loop poles move on the real axis towards each other on increasing the gain from 0 to 1. The third pole is away from these two dominant poles for K in 0 to 1.
Also we can clearly see that on increasing the gain, the steady state value is moving closer to 1. Hence, we can easily say that the steady state error is decreasing.

1.5 Problem e

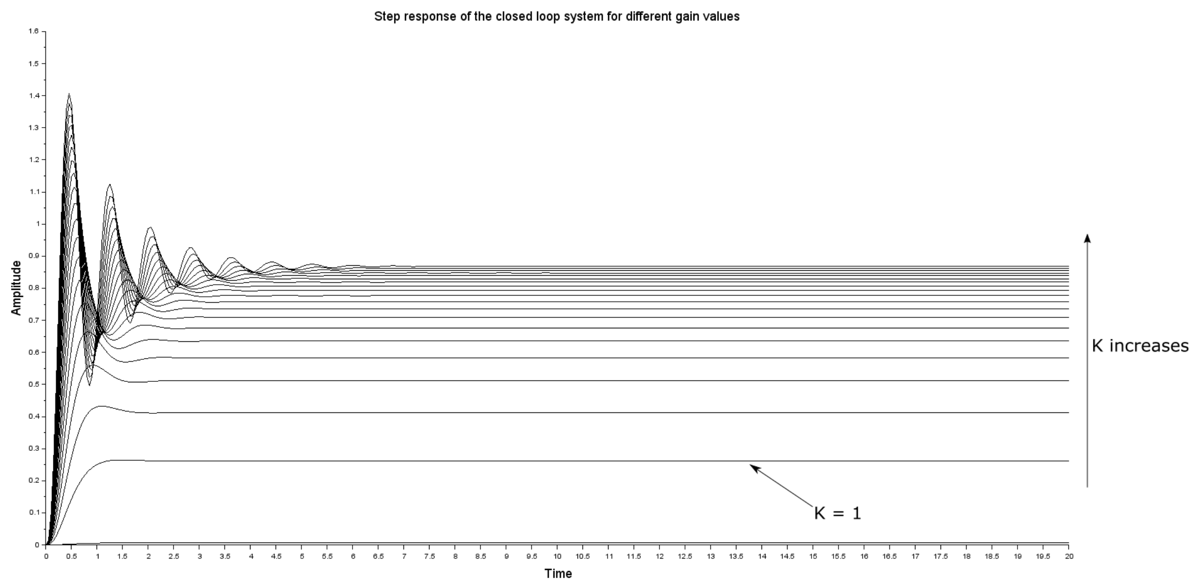
Now, we increase gain from 1 to 1000 in steps of 50.

Scilab Code

```
clear
clc

s = poly(0,'s');
G = 1/((s+3)*(s+4)*(s+12));

for k = 1:50:1000
    T = k*G/(1+ k*G);
    T1 = syslin('c', T);
    t = 0:0.05:20;
    ts1 = csim('step' , t , T1);
    //if (k == 1)
    //     plot2d(t,ts1,'-o');
    //else
        plot2d(t,ts1);
    //end
```

```
end
xlabel('Time','fontsize',4);
ylabel('Amplitude','fontsize',4);
title('Step response of the closed loop system for different gain values', '
    fontsize', 4)
```

Obtained plot



Observations

From the obtained step responses, we can see that the step response for K=1 is similar to a second order overdamped system. For higher K the response is similar to that of an underdamped second order system. Hence, we can say that the two dominant poles of the closed loop system move towards each other when K increases from 1. Somewhere, between K=1 and K=50 (which is first step response similar to an underdamped second order system) the two poles break away and we start getting complex poles. As the values of K is increased further the two poles move away from the real axis as the rise time is decreasing. Also, since the settling time for responses for system with K>=50 is increasing we can easily say that the real parts of these two dominant poles is decreasing. Since the response stays similar to that of a second order system, we can say that the third pole of the closed loop system stays away from these two dominant poles.
Also from the above plot we can see that the steady state value is moving closer to 1 and hence the steady state error is decreasing. Also we can se that the system remains stable until a gain of 1000