EE 324 Control Systems Lab

Problem Sheet 8

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Question 1

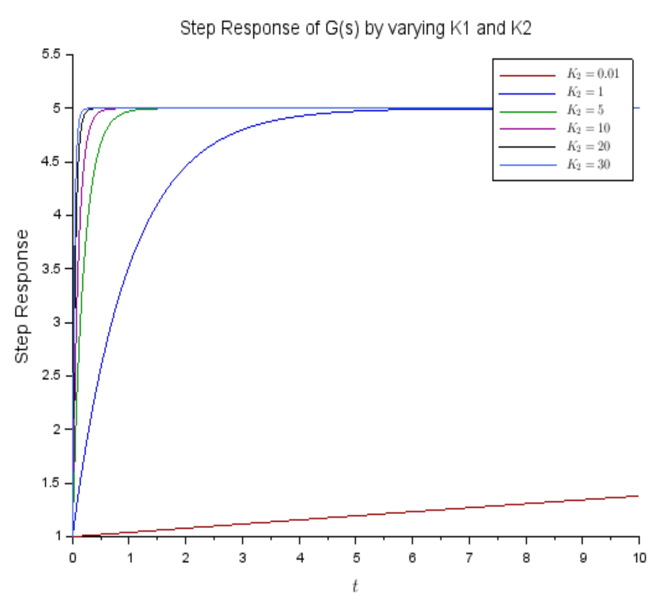
We've been given a Lag compensator with transfer function,

$$G(s) = \frac{s + K_1}{s + K_2}$$

Part (a) :
Keeping the ratio of K1/K2 = 5 move both the pole and zero away from the origin and towards the origin, and comment on the transient behavior of the system.
Step Response of the system will be,

$$c(t) = \frac{K_1}{K_2} - \frac{K_1 - K_2}{K_2} e^{-K_2 t}$$

Step Response of G(s) by varying K1 and K2 using `SciLab` is,



We can notice from the plots that, as the pole moves farther away from the origin, the transients decay faster.

```
s = poly(0, 's');
K2 = [0.01, 1, 5, 10, 20, 30];
K1 = 5*K2;
```

```
t = 0:0.01:10;
for i=1:size(K2, 2)
    k2 = K2(i);
    k1 = K1(i);
    G = syslin('c', (s+k1)/(s+k2));
    plot2d(t, csim('step', t, G));
end
xlabel("t");
ylabel("Step Response");
title("Step Response of G(s) by varying K1 and K2");
legend(["$K_2 = 0.01$", "$K_2 = 1$", "$K_2 = 5$", "$K_2 = 10$","$K_2 = 20$", "$K_2 = 30$"]);
```

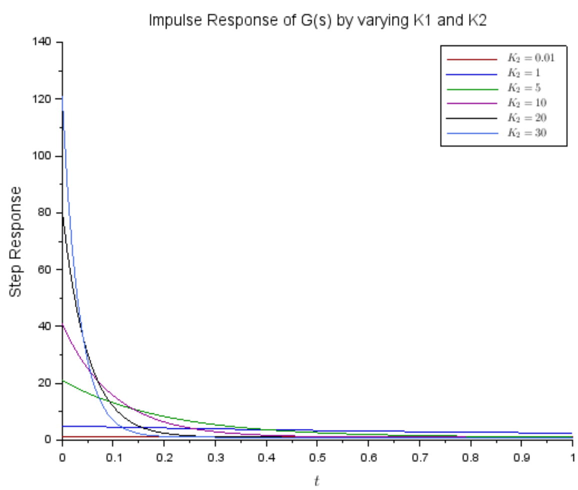
Part (b) :

Keeping the ratio of K1/K2 = 5 move both the pole and zero away from the origin and towards the origin, and comment on the impulse response of the system.

Impulse Response of the system will be,

$$h(t) = \delta(t) - (K_1 - K_2)e^{-K_2 t}$$

Impulse Response of G(s) by varying K1 and K2 using `SciLab` is,




```
s = poly(0, 's');
K2 = [0.01, 1, 5, 10, 20, 30];
K1 = 5*K2;
t = 0:0.01:1;
for i=1:size(K2, 2)
    k2 = K2(i);
    k1 = K1(i);
    G = syslin('c', (s+k1)/(s+k2));
    plot2d(t, csim('impuls', t, G));
end
xlabel("t");
ylabel("Step Response");
title("Impulse Response of G(s) by varying K1 and K2");
legend(["$K_2 = 0.01$", "$K_2 = 1$", "$K_2 = 5$", "$K_2 = 10$","$K_2 = 20$", "$K_2 = 30$"]);
```

Question 2

Find the two phase-crossover frequencies following the given steps

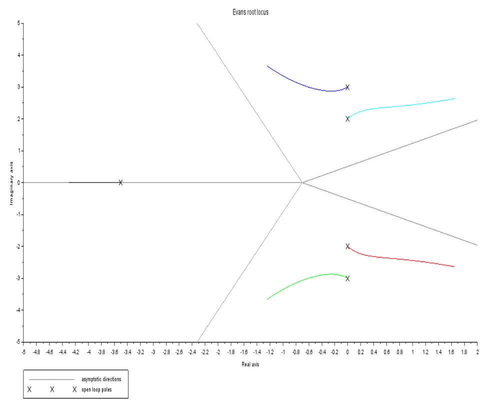
Part (a) :

Consider 4 non-repeating poles on the imaginary axis and one real pole

I chose the poles as -3.5, ± 2i and ± 3i

$$G(s) = \frac{1}{(s+3.5)(s^2+4)(s^2+9)}$$

Root Locus of G(s) using `SciLab` is,




```
s = poly(0, 's');
Pole1 = -3.5;
Pole2 = 2*%i;
Pole3 = -2*%i;
Pole4 = 3*%i;
Pole5 = -3*%i;
G = syslin('c', 1/((s-Pole1)*(s-Pole2)*(s-Pole3)*(s-Pole4)*(s-Pole5)));
evans(G, 500);
```

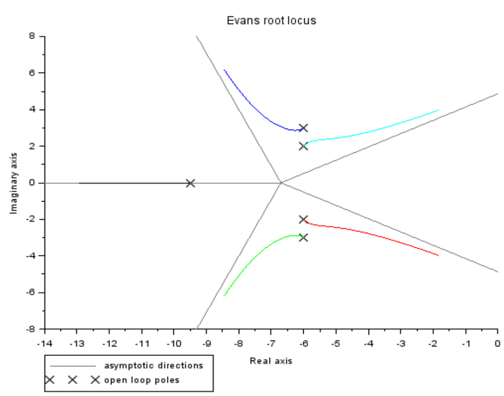
Part (b) :

Shift the origin of the root locus such that all the poles lie in the left half-plane.

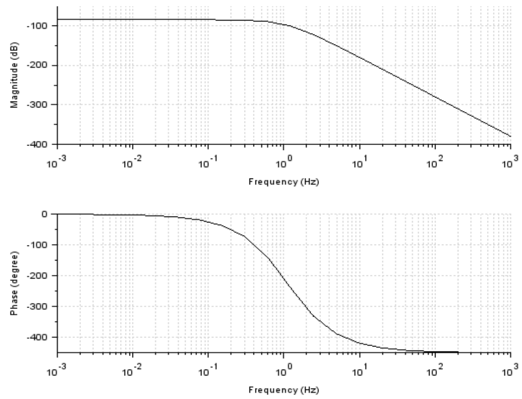
I shifted the origin by 6 units to the left, then the Transfer Function becomes,

$$G_{Shifted}(s) = \frac{1}{(s+3.5+6)(s^2+4+6)(s^2+9+6)}$$

Root Locus of shifted G(s) using `SciLab` is,



Bode Plot of shifted G(s) using `SciLab` is,

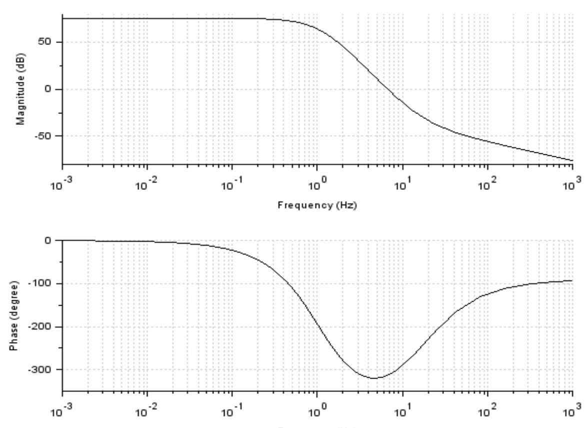



```
Shift = 6;
G_Shift = syslin('c', 1/((s−Pole1+Shift)∗(s−Pole2+Shift)∗(s−Pole3+Shift)∗(s−Pole4+Shift)∗
(s−Pole5+Shift)));
evans(G_Shift, 10000);
scf();
bode(G_Shift);
```

Part (c) :
By looking at the above bode plot, we can conclude that we already have one phase crossover. We need one more. For that to happen, we need to add zeros such that the phase response rises after it falls below 180 degrees. This means we have to add 4 zeros at least (as we have 4 poles) and we have to add the zeros sufficiently left of the farthest pole from the origin. I add 4 zeros located at -100 to the origin-shifted transfer function.
The modified Transfer Function, thus, is,

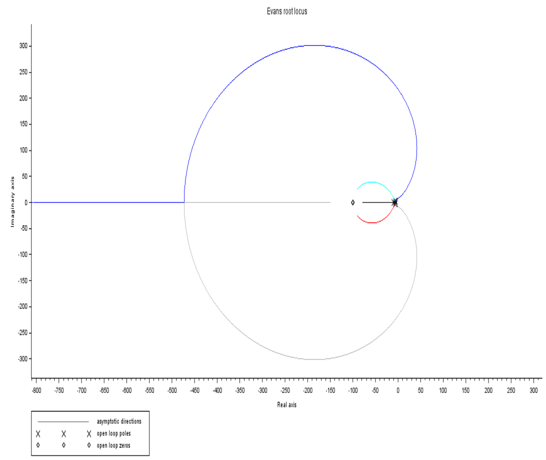
$$G_{Modified}(s) = \frac{(s+100)^4}{(s+3.5+6)(s^2+4+6)(s^2+9+6)}$$

The modified bode plot with two phase-crossover frequencies using `SciLab` is,




```
Zero = 100;
G_Modified = syslin('c', G_Shift∗(s+Zero)^4);
bode(G_Modified);
```

Part (d) :
Root Locus of the modified system using `SciLab` is,



By noticing figure, we can conclude that this modified system satisfies the problem statement.

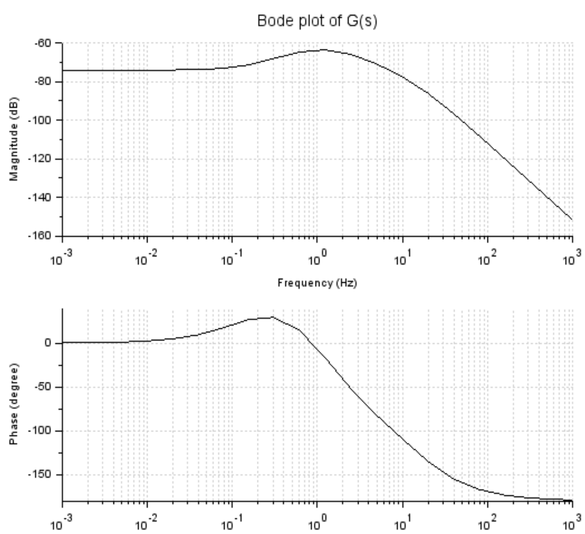
```
// Part d
evans(G_Modified, 10000);
```

Question 3

Figure out the corresponding transfer function. Afterward, plot the phase plot for the same.
By looking at the given plot, we can notice that there are 4 points where slope of the plots are changing. Those points are at $\omega = 1, 5, 10, 100$ respectively.
Out of these, at $\omega = 1$, the magnitude response is increasing whereas for $\omega = 5$, 10 and 100, magnitude response is decreasing.
Using this info, we can conclude there is a zero at $\omega = 1$ and poles are at $\omega = 5$, 10 and 100.
So the Transfer Function becomes,

$$G(s) = \frac{(s+1)}{(s+5)(s+10)(s+100)}$$

Bode Plot of the obtained function using `SciLab`,



```
s = poly(0, 's');
Zero = 1;
Pole1 = 5;
Pole2 = 10;
Pole3 = 100;
G = syslin('c', (s+Zero)/((s+Pole1)*(s+Pole2)*(s+Pole3)));
bode(G);
title(["Bode plot of G(s)"], 'fontsize', 3);
```

References

1) https://help.scilab.org/
2) https://spoken-tutorial.org/tutorial-search/?search_foss=Scilabsearch_language=English
3) https://spoken-tutorial.org/tutorial-search/?search_foss=Scilabsearch_language=Englishpage=2