

EE 324 Control Systems Lab

Problem Sheet 9

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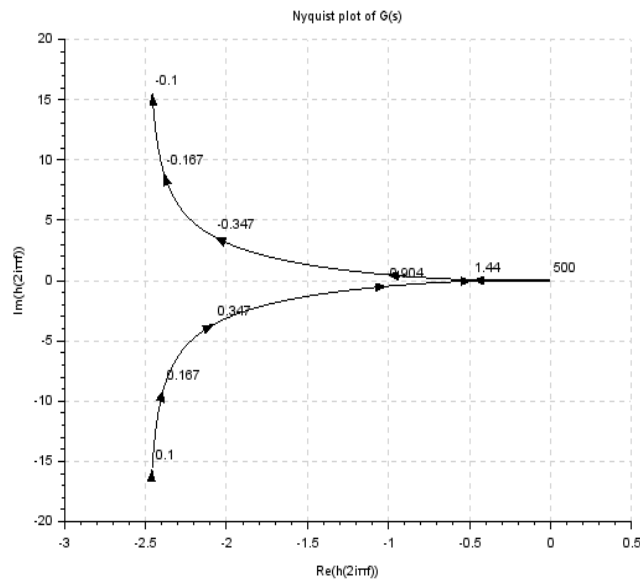
October 16, 2021

Question 1

We've been given an open loop transfer function,

$$G(s) = \frac{10}{s(s/5 + 1)(s/20 + 1)}$$

The Nyquist plot of $G(s)$ using SciLab is,



```

1 s = poly(0, 's');
2 G = syslin('c', 10/(s*((s/5)+1)*((s/20)+1)));
3 nyquist(G, 0.1, 500);
4 g_margin(G)
5 p_margin(G)

```

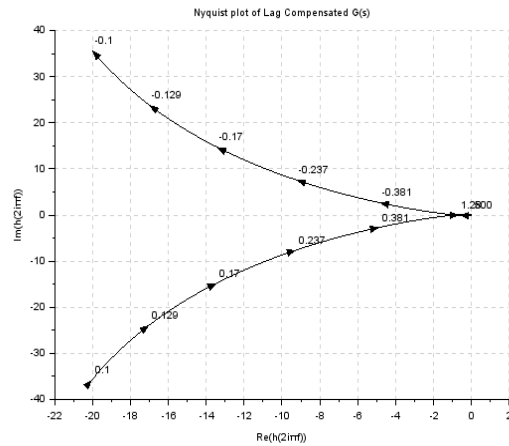
Part (i) :

$C(s)$ is a Lag Compensator

$$C(s) = \frac{s + 3}{s + 1}$$

$$\Rightarrow G_{LagComp} = C(s)G(s) = \frac{10(s + 3)}{s(s + 1)(s/5 + 1)(s/20 + 1)}$$

The Nyquist plot of $G_{LagComp}$ using SciLab is,



```

1 Lag_Comp = G*(s+3)/(s+1);
2 G_LagComp = syslin('c', Lag_Comp);
3 scf();
4 nyquist(G_LagComp, 0.1, 500);
5 g_margin(G_LagComp)
6 p_margin(G_LagComp)

```

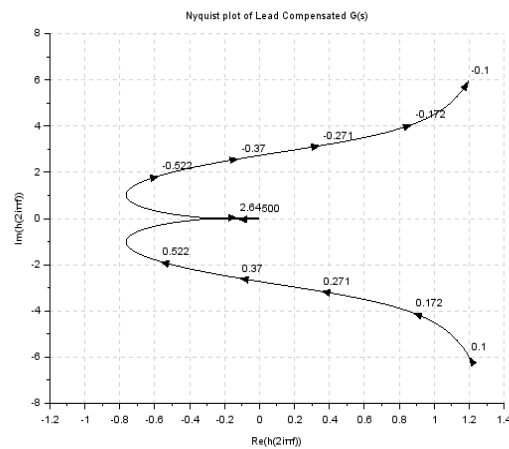
Part (ii) :

C(s) is a Lead Compensator

$$C(s) = \frac{s+1}{s+3}$$

$$\Rightarrow G_{LeadComp} = C(s)G(s) = \frac{10(s+1)}{s(s+3)(s/5+1)(s/20+1)}$$

The Nyquist plot of G_LeadComp using SciLab is,



```

1 Lead_Comp = G*(s+1)/(s+3);
2 G_LeadComp = syslin('c', Lead_Comp);
3 scf();
4 nyquist(G_LeadComp, 0.1, 500);
5 g_margin(G_LeadComp)
6 p_margin(G_LeadComp)

```

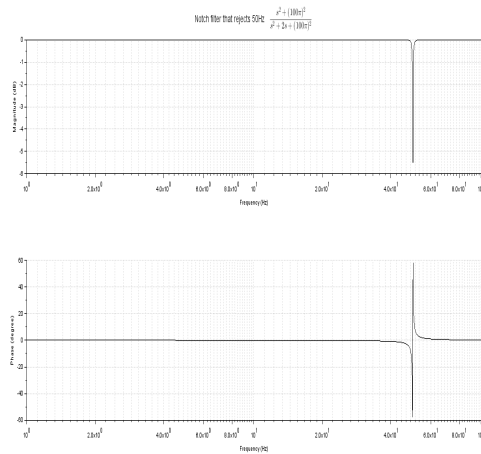
System	Gain Margin (in dB)	Phase Margin (in degrees)
$G_{LeadComp}(s)$	11.7595	43.1731
$G(s)$	7.9588	22.5359
$G_{LagComp}(s)$	2.0762	4.0427

Question 2

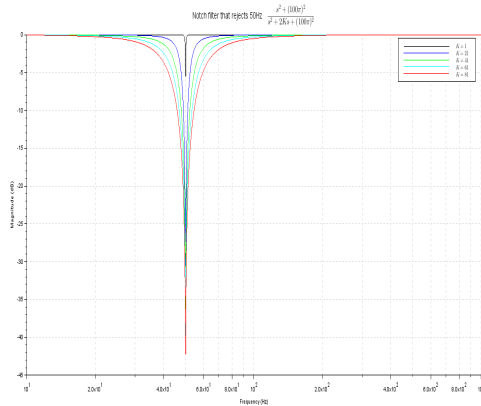
Notch filter system that rejects 50Hz signal is,

$$G(s) = \frac{s^2 + (100\pi)^2}{s^2 + 2s + (100\pi)^2}$$

Bode plot of $G(s)$ using SciLab is,



Now, we will vary gain K of the closed loop transfer function of $G(s)$



The steepness of the magnitude plot can be controlled by varying the real part of the poles of the transfer function. If the real part of the poles is far away from the origin, the steepness reduces.

```

1 s = poly(0, 's');
2 G = syslin('c', ((s^2+(100*pi)^2)/(s^2 + 2*s + (100*pi)^2)));
3 scf();
4 bode(G, 1, 100);
5 K = 1:20:100;
6 tfs = [];
7 labels = [];

```

```

8  for i=1:size(K, 2)
9      k = K(i);
10     G = syslin('c', ((s^2+(100*pi)^2)/(s^2 + 2*k*s + (100*pi)^2)));
11     tfs = [tfs; G];
12     str = sprintf("$K = %d$", k);
13     labels = [labels; str];
14 end
15 scf();
16 gainplot(tfs, 10, 1000, labels);

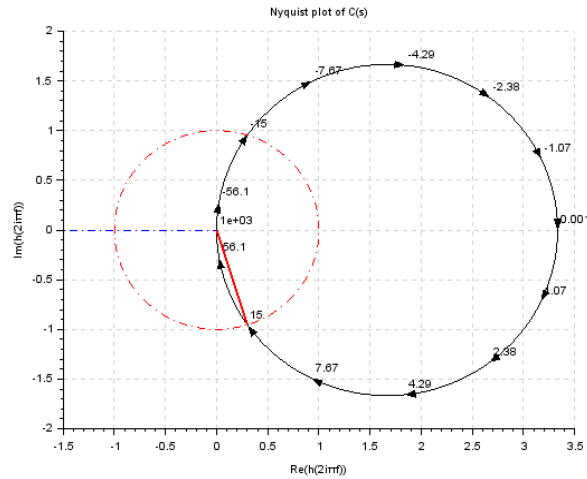
```

Question 3

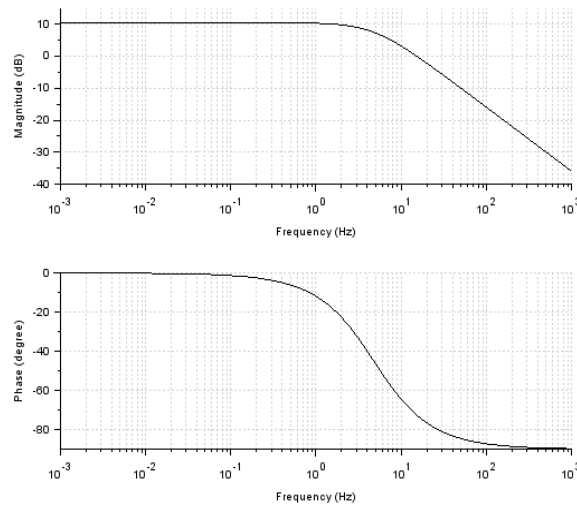
System given to us is,

$$C(s) = \frac{100}{s + 30}$$

Nyquist plot of the system using SciLab,



Bode plot of the system using SciLab,



From the Nyquist diagram, we can conclude that the gain margin of $C(s)$ is 0dB and the phase margin is 107.45760312 degrees with gain crossover frequency of 15.18241393 Hz. Hence, the minimum delay required

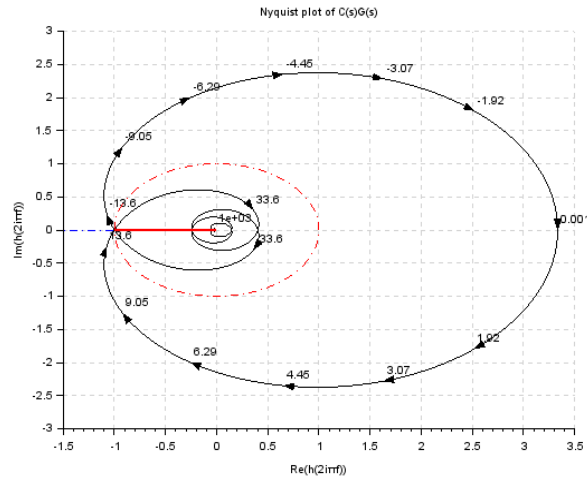
to destabilize the closed-loop system is,

$$T = \frac{PM}{\omega_{gcf}} = 0.01966s$$

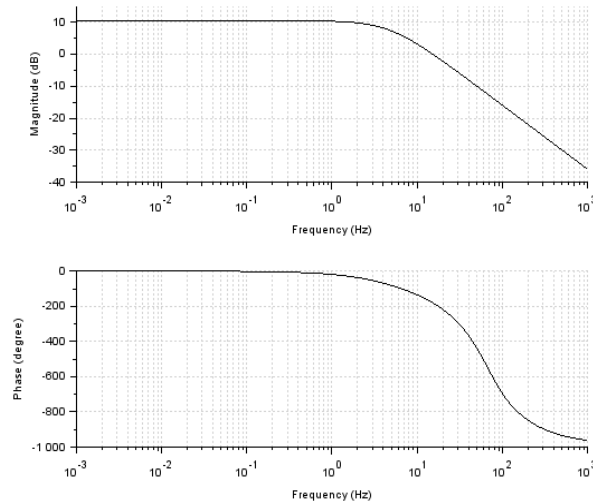
Using Pade's approximation to model e^{-sT} ,

$$e^{-sT} \approx \frac{1 - 0.5sT + (1/9)(sT)^2 - (1/72)(sT)^3 + (1/1008)(sT)^4 - (1/30240)(sT)^5}{1 + 0.5sT + (1/9)(sT)^2 + (1/72)(sT)^3 + (1/1008)(sT)^4 + (1/30240)(sT)^5}$$

The Nyquist diagram of $C(s)G(s)$ where $G(s)$ is the delay using **SciLab** is,



The Bode diagram of $C(s)G(s)$ where $G(s)$ is the delay using **SciLab** is,



The new phase margin is now 0.00000529 and the new gain margin is 0.07814458dB.

```

1 s = poly(0, 's');
2 C = syslin('c', 100/(s+30));
3 [Phase_m, fm] = p_margin(C)
4 g_margin(C)
5 Phase_m
6 fm

```

```

7  scf();
8  show_margins(C, 'nyquist');
9  T = Phase_m(%pi/180)/(2*pi*fm);
10 CG = syslin('c', C*(1-0.5*s*T+(1/9)*(s*T)^2-(1/72)*(s*T)^3+(1/1008)*(s*T)^4
11      -(1/30240)*(s*T)^5)/(1+0.5*s*T+(1/9)*(s*T)^2+(1/72)*(s*T)^3+(1/1008)*(s*T)^4+(1/30240)*(s*T)^5));
12  scf();
13  show_margins(CG, 'nyquist');
14  g_margin(CG)
15  p_margin(CG)
16  scf();
17  bode(C);
18  scf();
19  bode(CG);

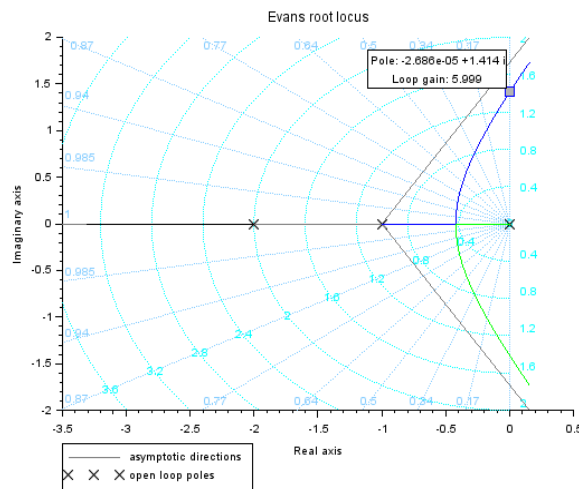
```

Question 4

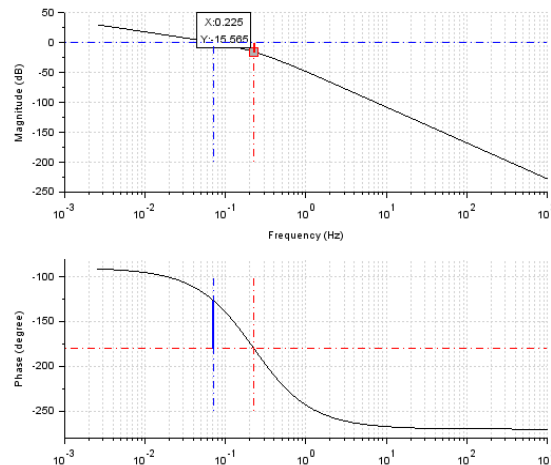
Given open loop transfer function is,

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

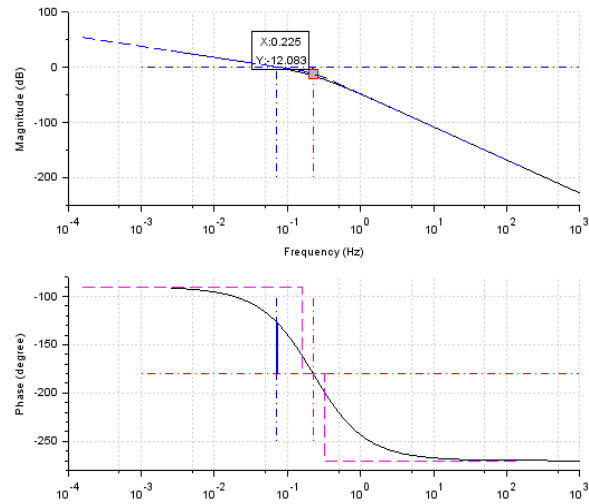
Root Locus of the given system using SciLab is,



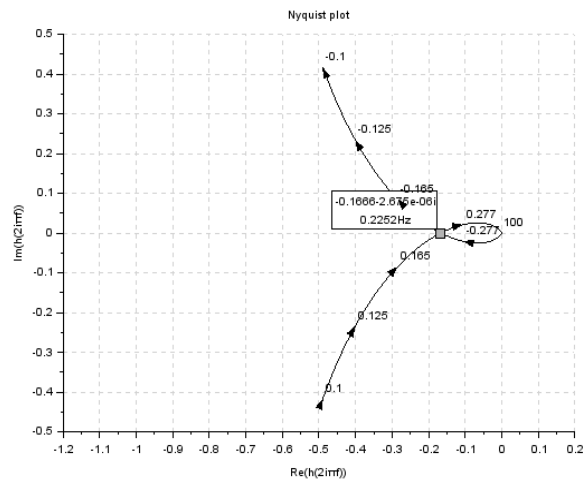
Bode Plot of the given system using SciLab is,



Asymptotic Bode Plot of the given system using SciLab is,



Nyquist Plot of the given system using SciLab is,



Technique	Gain Margin (in dB)
Root Locus	15.5616
Bode Plot	15.565
Asymptotic Bode Plot	12.803
Nyquist Plot	15.5665

```

1 s = poly(0, 's');
2 G = syslin('c', 1/(s^3 + 3*s^2 + 2*s));
3 Kr = kpure(G);
4 Gain_m = 20 * log(Kr) / log(10);
5 Gain_m
6 scf();
7 evans(G, 10);
8 sgrid;
9 scf();
10 show_margins(G, 'bode');
11 scf();

```

```

12 bode_asymp(G);
13 scf();
14 nyquist(G, 0.1, 100);

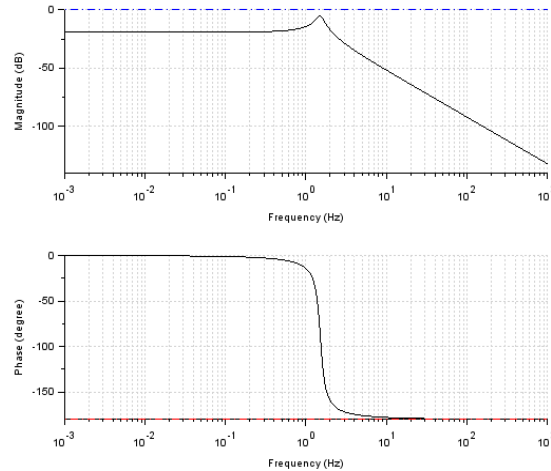
```

Question 5

Given open loop transfer function is,

$$G(s) = \frac{10s + 2000}{s^3 + 202s^2 + 490s + 18001}$$

Bode Plot of the given system using **SciLab** is,



The Gain Margin is infinity and the Phase Margin is not defined.

To get the steady state error as 10%, the proportional gain $K = 81.0045$.

Hence,

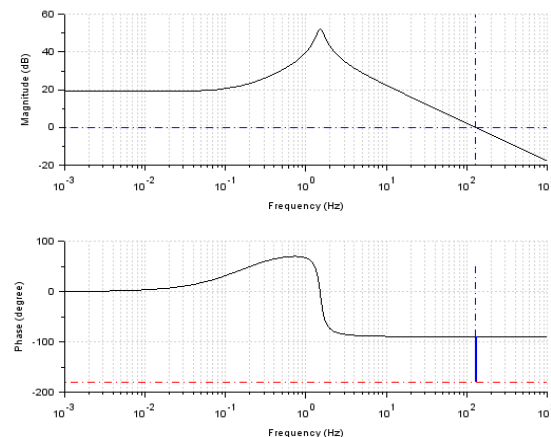
$$G1(s) = \frac{81.0045(10s + 2000)}{s^3 + 202s^2 + 490s + 18001}$$

The gain margin for $G1$ is also infinity and the phase margin is 4.24260124 degrees and the gain crossover frequency is 4.76888914Hz. To improve the phase margin of $G1$ such that the new phase margin is greater than or equal to 90 degrees, without altering the dc gain, we cascade $G1$ with $s+1$.

$$G1(s) = \frac{81.0045(10s + 2000)(s + 1)}{s^3 + 202s^2 + 490s + 18001}$$

As we are adding a unit zero, this does not alter the dc gain.

The Bode plot of the modified system using **SciLab** is,



The new gain margin is 0dB, phase margin is 90.07074111 degrees and the gain crossover frequency is 128.94005171Hz. The closed loop poles of the modified system are -810.93512,-199.99999,-1.1098916. Hence, it is closed-loop stable.

```
1 s = poly(0, 's');
2 G = syslin('c', (10*s+2000)/(s^3 + 202*s^2 + 490*s + 18001));
3 show_margins(G, 'bode');
4 K = 9*18001 / 2000;
5 G1 = syslin('c', K*G);
6 K
7 [Gain_m, fg] = g_margin(G1);
8 [Phase_m, fp] = p_margin(G1);
9 Gain_m
10 fg
11 Phase_m
12 fp
13 G2 = syslin('c', G1*(s+1));
14 [Gain_m2, fg2] = g_margin(G2);
15 [Phase_m2, fp2] = p_margin(G2);
16 Gain_m2
17 fg2
18 Phase_m2
19 fp2
20 G2_Closed = G2/.syslin('c', 1, 1);
21 [zero, pole, gain] = tf2zp(G2_Closed);
22 pole
23 scf();
24 show_margins(G2);
```

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