EE 105 Feedback Control Systems
Department of Electrical and Computer Engineering
Tufts University Fall 2018
Homework #9

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1 Problem 1

1.1 Part A

For ideal Op-Amp,

$$\frac{v_{out}}{v_{in}} = -\frac{Z_{out}}{Z_{in}}$$

where

$$Z_{in} = (\frac{1}{sC} + R_2)//R_1; \quad Z_{out} = R_1$$

So

$$D(s) = -\frac{v_{out}}{v_{in}} = \frac{(R_1 + R_2)s + 1}{R_2 C s + 1}$$

We have

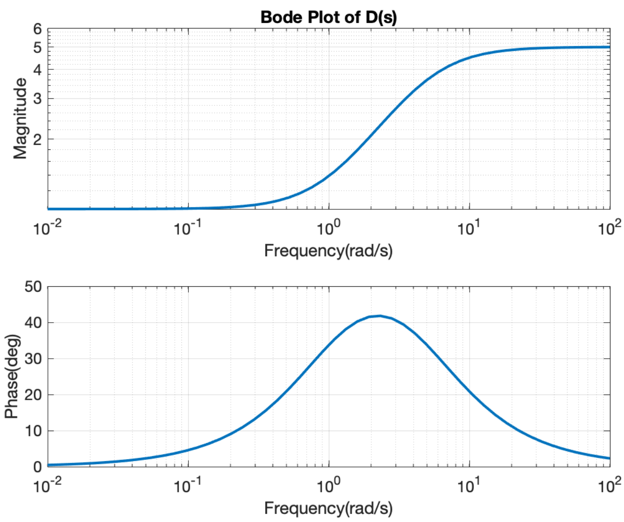
$$(R_1 + R_2)C = \frac{1}{0.2} R_2 C$$

So I choose parameters

$$R_1 = 80\ \text{k}\Omega, \quad R_2 = 20\ \text{k}\Omega, \quad C = 10\ \mu\text{F}$$

1.2 Part B

The bode plot of $D(s)$(after applying the unit inverter)



We can see the turning point at about $\omega = 1$ and 5.

1.3 Part C

Say V_m is the votage of the inverting input.

$$\begin{cases} V_{out} = -V_m \dfrac{A_0}{\tau s + 1} \\ V_m = V_{in} + \dfrac{Z_{in}}{Z_{in} + Z_{out}}(V_{out} - V_{in}) \end{cases}$$

eliminate V_m,

$$\frac{V_{out}}{V_{in}} = -\frac{Z_{out}}{Z_{in}} \frac{A_0}{(\tau s+1)(1+\frac{Z_{out}}{Z_{in}})+A_0} = -D(s)\frac{L(s)}{1+L(s)}$$

where

$$L(s) = \frac{A_0}{(\tau s+1)(D(s)+1)} = \frac{A_0}{2}\frac{\alpha s+1}{(\tau s+1)(\beta s+1)}$$

In which,

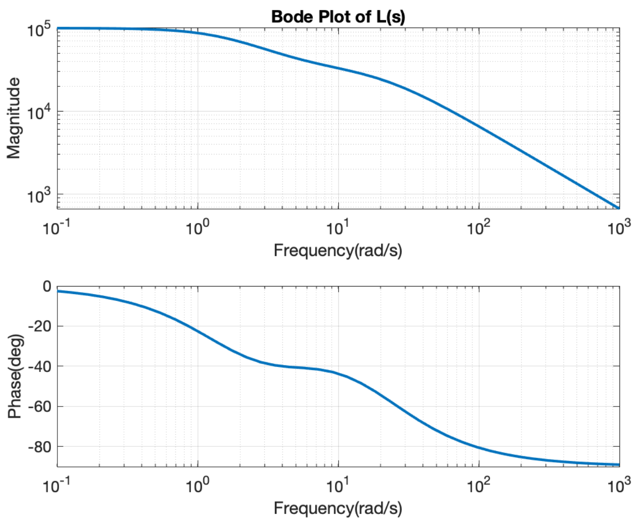
$$\alpha = R_2 C, \quad \beta = (\frac{R_1}{2}+R_2)C$$

1.4 Part D

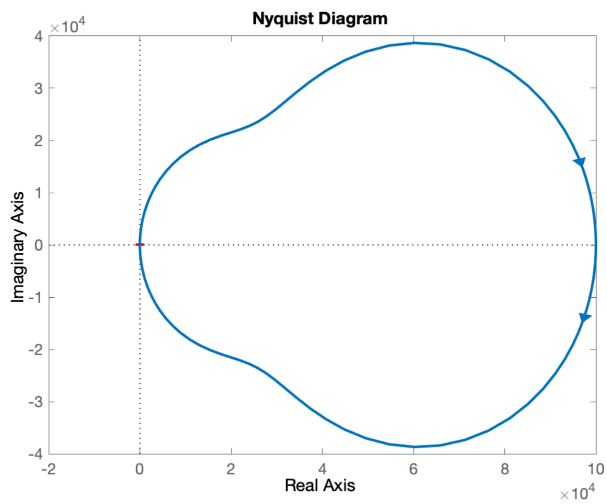
Substitute these quantity into $L(s)$,

$$L(s) = \frac{20000s+100000}{0.03s^2+0.65s+1}$$

The bode plot,



And the Nyquist plot,



1.5 Part E

According to the Bode plot, the phase of $L(s)$ will never be lower than 90 degree. So the close loop system is stable.