EC5301:CONTROL SYSTEMS DESIGN

ASSIGNMENT

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REG. NO	:	EG/2022/5322
DATE	:	30/12/2025

1.Consider the transfer function model of the closed-loop position control system shown in Figure

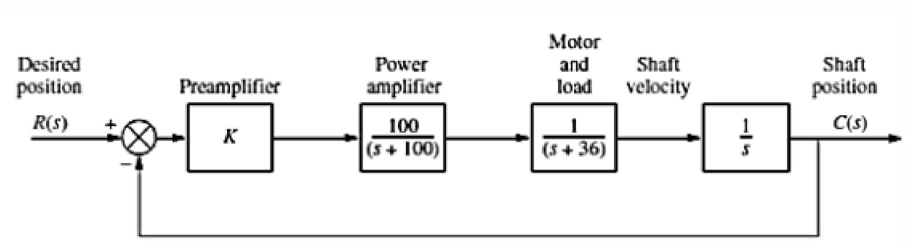


Fig. 1

Section A

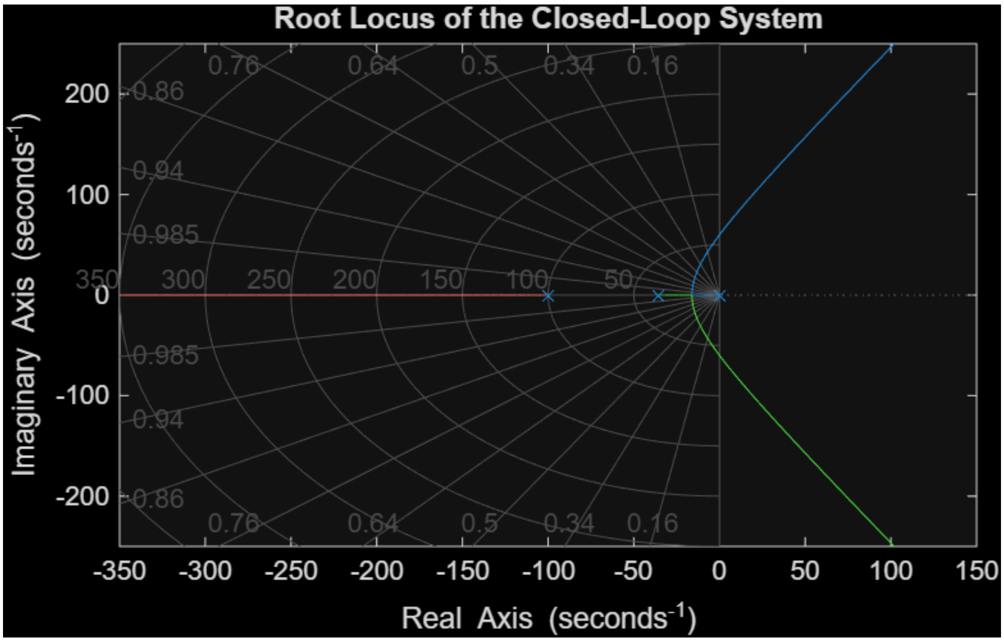
i. Determine the open-loop transfer function of the system for a preamplifier gain of K = 1. [1 mark]

$G(s)=K\times\frac{100}{s+100}\cdot\frac{1}{s+36}\cdot\frac{1}{s}$

For k = 1

$G(s)=\frac{100}{s(s+100)(s+36)}$

ii. Using MATLAB, obtain the root locus of the closed-loop system as the gain K is varied from 0 to infinity. [1 mark]



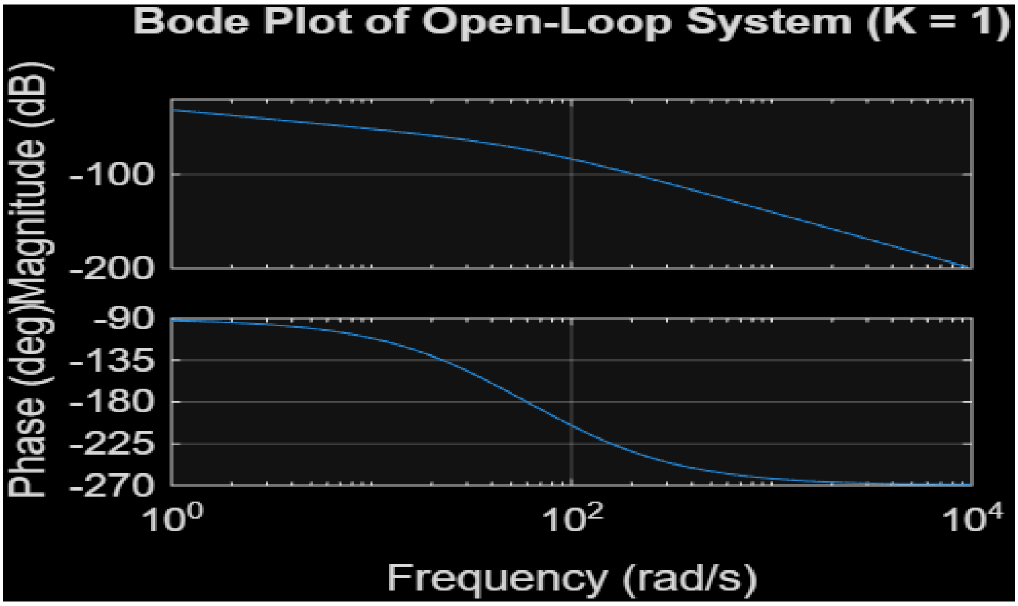
iii. Based on the root locus obtained, determine the range of values of K for which the closed loop system remains stable. [1 mark]

- From the root locus, the system becomes unstable for large values of K.

Section B

You are required to design the gain K such that the percent overshoot of the system's transient response to a unit step input is 10%, using frequency response techniques and MATLAB.

i. Using MATLAB, obtain the Bode plot of the open-loop transfer function assuming K = 1. [1 mark]



- PM = 89.94°

ii. Stating any assumptions made, calculate the required phase margin that will result in a 10% overshoot in the step response. [1 mark]

- $\zeta \approx 0.59 \Rightarrow \Phi M \approx 59^\circ$

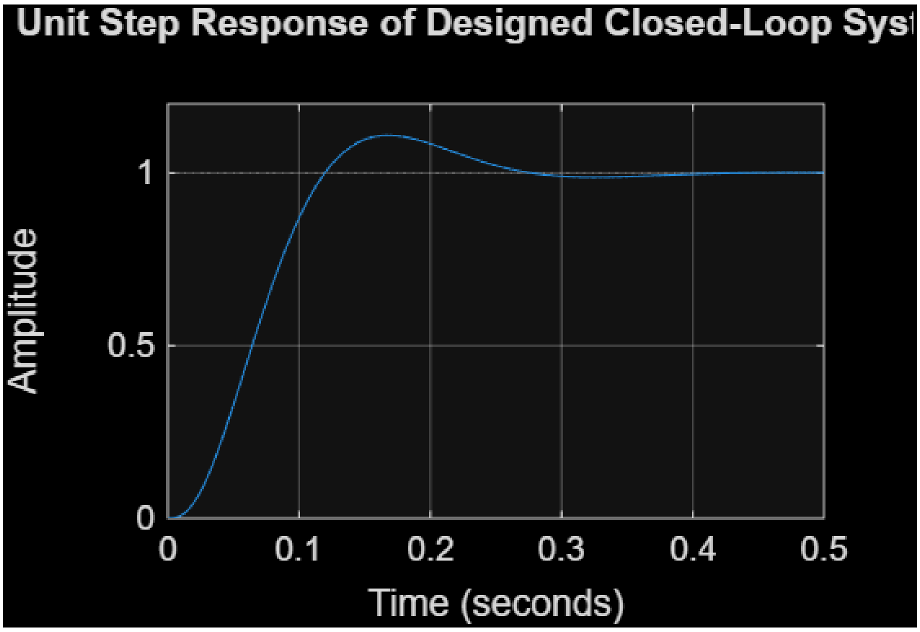
iii. Using the Bode phase plot, determine the frequency $\omega\Phi M$ at which the desired phase margin ΦM is achieved. [2 marks]

- `Frequency at desired phase margin (rad/s): 16.0426`

iv. Using the Bode magnitude plot and the frequency identified in Part iv, determine the required value of the gain K that satisfies the design requirement. [2 marks]

- `Required Gain K = 640.369`

v. Obtain the unit step response of the designed system and check whether the specified percent overshoot requirement is met. [1 mark]



MATLAB Code

```
clc;
clear;
close all;
%% Define the open-loop transfer function (K = 1)
% Numerator and denominator
num = 100;
den = conv([1 0], conv([1 36], [1 100])); % s(s+36)(s+100)
% Open-loop transfer function
G = tf(num, den);
disp('Open-loop transfer function G(s) = ');
G
%% ========================
% SECTION A
% ========================
%% Section A(ii): Root Locus Plot
figure;
rlocus(G);
grid on;
title('Root Locus of the Closed-Loop System');
%% Section A(iii): Stability Range of K
disp('Use the root locus plot to determine the stability range of K.');
```

```
%% ========================
% SECTION B
% ========================
%% Section B(i): Bode Plot of Open-Loop System (K = 1)
figure;
bode(G);
grid on;
title('Bode Plot of Open-Loop System (K = 1)');
%% Section B(ii): Required Phase Margin for 10% Overshoot
PM_required = 59;
disp(['Required Phase Margin for 10% Overshoot ≈ ', num2str(PM_required), ' degrees']);
%% ==========================================================
% Section B(iii): Frequency at which required phase margin occurs
% ==========================================================
% Obtain Bode data
[mag, phase, w] = bode(G);
mag = squeeze(mag);
phase = squeeze(phase);
% Desired phase corresponding to required phase margin
desired_phase = -180 + PM_required; % -121 degrees
% Find frequency where phase is closest to desired value
[~, idx] = min(abs(phase - desired_phase));
w_phiM = w(idx);
disp(['Frequency at desired phase margin (rad/s): ', num2str(w_phiM)]);
%% ==========================================================
% Section B(iv): Calculate required gain K
% ==========================================================
% Magnitude at the selected frequency
mag_at_w = mag(idx);
% Required gain
K_required = 1 / mag_at_w;
disp(['Corrected Required Gain K = ', num2str(K_required)]);
%% ==========================================================
% Section B(v): Closed-loop step response with designed gain
% ==========================================================
% Closed-loop transfer function



T = feedback(K_required * G, 1);
% Check closed-loop poles
disp('Closed-loop poles:');
disp(pole(T));
% Step response
figure;
step(T);
grid on;
title('Unit Step Response of Designed Closed-Loop System');
% Step response characteristics
info = stepinfo(T);
disp('Step Response Information:');
disp(info);
```