Problem 1

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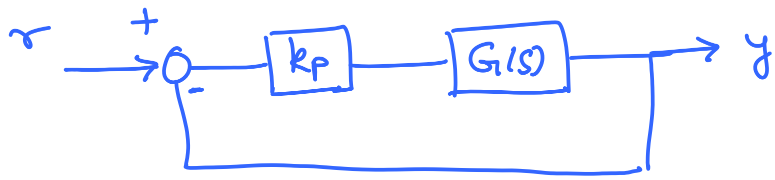
Proportional Controller



In the unity negative feedback interconnection shown above kp is a constant that needs to be designed. $G(s) = \dfrac{100}{s^3 + 6s^2 + 5s}$.

(a) Find the gain margin and phase margin of the system when $k_p = 1$.
Determine if the closed-loop system is stable or not with $k_p = 1$

(b) Design kp such that the phase margin is approximately 25°. Predict the maximum overshoot M_p for a step-input r using the intuition from second order systems (For second order systems $PM = 100\zeta$).

Problem 1 continued

(c) With the k_p designed in Part (b) above plot the Bode of new open loop $k_p G(s)$. What are the Gain and phase Margins?

(d) Use Matlab to obtain the step response of the closed-loop system. Comment on the step response characteristics

Problem 2

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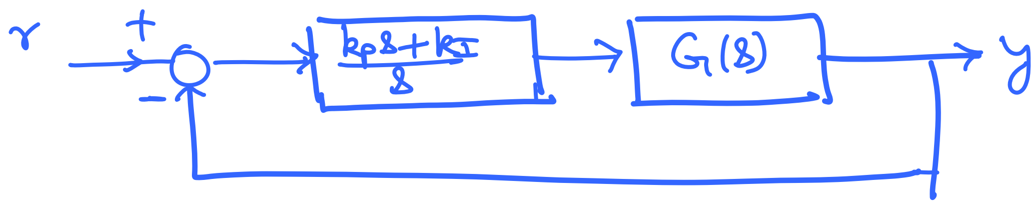
Proportional-Integral Controller:



Consider the unity negative feedback system shown above with a proportional integral controller $K(s) = \frac{k_p s + k_I}{s}$ and

$$G(s) = \frac{500}{s^2 + 6s + 5}.$$

(a) obtain the asymptotic Bode plot of the controller $K(s) = \frac{k_p s + k_I}{s}$ with the asymptotic gain and phase values identified.

(b) Let the controller K(s)=1 for this part of the question. Analytically evaluate the steady-state error due to a Step input and compare it with the Steady state error obtained using Matlab. What is the type of the System?

Part c

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(c) The goal of this part of the problem is to find k_p and k_I such that

(i) $M_p \leq 16\%$ and

(ii) e_{ss} to ramp is less than 0.5

(I) - Translate the condition $M_p \leq 16\%$ to a phase margin specification: show all the steps.

(II) - Determine the range in which k_I has to lie for specification (ii) to be met

(III) - Design a proportional controller k_p (similar to problem 1) so that the phase margin condition resulting from M_p specification is met

(IV) - Design the integral constant k_I such that the gain crossover frequency of $k_p G(s)$ is not affected. This can be achieved by choosing

$$\frac{k_I}{k_p} \leq \frac{\omega_{gc}}{10}$$ [where ω_{gc} is the gain crossover frequency of $k_p G$]

(V) - Evaluate if the the steady-state error requirement is met. If not iterate the design appropriately.

Part c

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VI

- Plot the Bode plot of $k_p G(s)$ and the Bode plot of $\frac{s + k_I/k_p}{s}$ on the same plot. Comment on the plot.

VII Plot the Bode of $\left[\frac{k_p s + k_I}{s}\right] G(s)$ and obtain the PM and GM.

VIII Obtain the step-response of the closed-loop.

Problem 3 (Lead controller)

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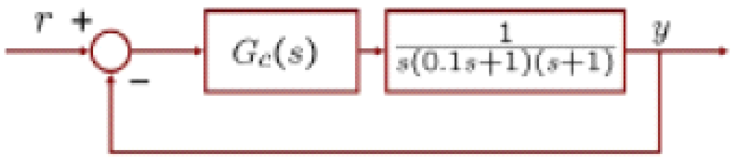
P3 Lead Controller

3. Consider the figure given below. Design a lead controller $G_c(s)$ such that the phase margin



is at least 45^o, gain margin is at least 8 dB and static velocity error constant K_v is 4 sec^{-1}. Plot the unit step and unit ramp responses using Matlab.

Problem 4 (Lag Controller)

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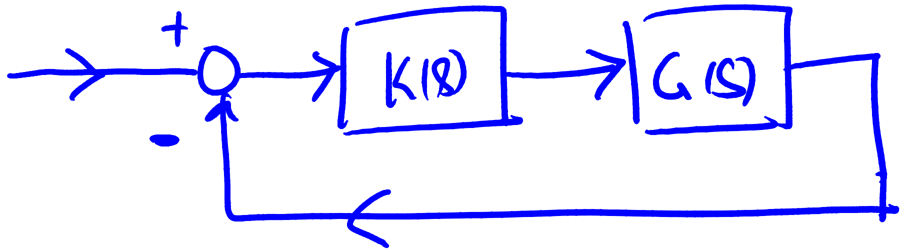
Consider the following feedback interconnection



Where $G = \dfrac{40}{s(s+2)}$

Design a Lag Controller such so that the Phase margin is 45 degrees and the k_v=20.

Problem 5

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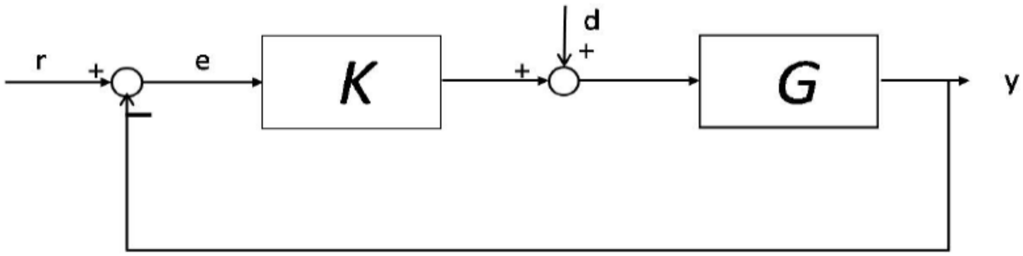

Figure 1:

Problem 1: (PID Controller design)The block diagram of a control system is shown in Figure 1. In Figure 1, r is the reference input, d is disturbance, y is the measured output, e is the error, and the controller is K.

The plant is

$$G(s) = \frac{1.8}{s^3 + 2s^2}.$$

The controller has the PID form

$$K = \underbrace{(1 + k_d s)}_{PD} \underbrace{(k_p + \frac{k_I}{s})}_{PI}$$

where $PD = (1 + k_d s)$ and $PI = (k_p + \frac{k_I}{s})$. The specifications that have to be met are

- Zero steady state error when d is a step input.
- A phase margin of 65 degrees
- A desired gain cross over frequency, ω_{gcd} of 0.5 rad/sec.

1. (5pts) Find the transfer function from the disturbance d to the signal e (assume $r = 0$) and show that the steady state in the error e when d is a step is zero. Is a zero steady state error, when d is a step, possible for the given plant G if the integral part of the controller is not present? Provide reasons.
2. (5pt) Is it possible to meet the design specification if a PI controller (without the PD part) is used. Provide reasons

Problem 5 Continued

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3. (20 pts) You will first design the PD part.

   (a) Determine the parameter k_d such that at the desired gain cross-over frequency, the phase of $PD*G$ is such that the phase margin requirement of 65 degrees is met (do not add any safety margin).

   (b) Draw the bode plot of $PD*G$ and determine if at ω_{gcd} the desired phase is satisfied.

4. (20) Now you will design the PI part

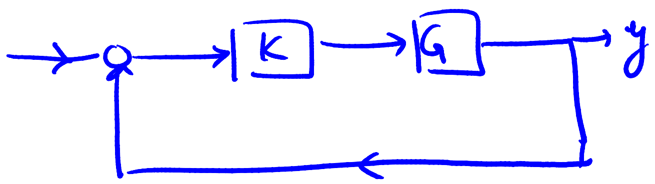
   (a) Let $G_1 = PD * G$. Using G_1 as the new plant, design the PI part of the controller to force the gain cross over of $G_1 * PI$ to be at ω_{gcd} and that the phase margin obtained by the PD design step is not affected.

   (b) Plot bode plot of $G_1 * PI$ which is same as $K * G$. Iterate the PI step to make sure that the phase margin requirement is met.

   (c) Plot the step response of the system when d is a unit step. Comment on the step response.

Problem 6

Consider the unity negative feedback interconnection



(a) Give an example of G and K transfer functions, if possible, such that $\frac{1}{1+KG}$ and $\frac{G}{1+GK}$ are stable but $\frac{K}{1+GK}$ is not

(b) Give an example of G and K transfer functions, if possible, such that $\frac{K}{1+KG}$ and $\frac{G}{1+GK}$ are stable but $\frac{1}{1+GK}$ is not

(c) Give an example of G and K transfer functions, if possible, such that $\frac{1}{1+GK}$ and $\frac{K}{1+GK}$ are stable but $\frac{G}{1+GK}$ is not