EE 113 - Introduction to Electrical Engineering Practice

Control Systems

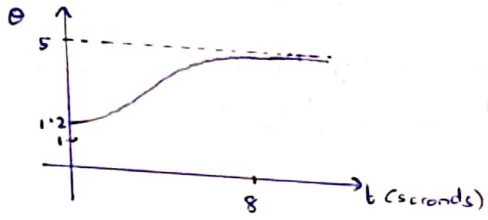
Questionnaire- 2

[SOLUTIONS]

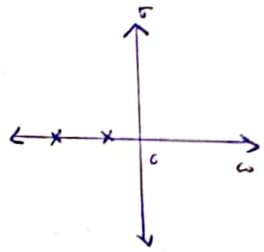
A. Position Control – Proportional only (Turn off disturbance)

1. How does K_p affect the response: Draw responses to the 5 rad step input for:-

(2 marks) a) Low K_p $k_p \rightarrow (0.01 \rightarrow 0.09)$

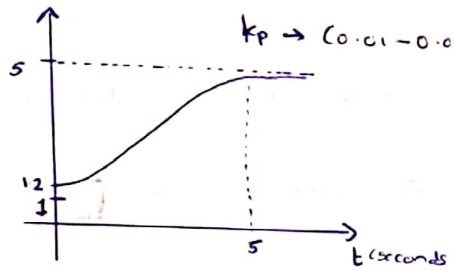


(1 mark)

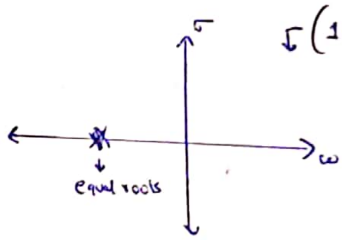


(2 marks) b) Highest K_p without oscillation

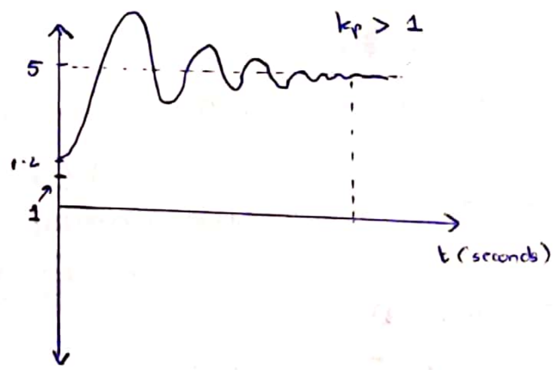
$k_p \rightarrow (0.01 - 0.09)$



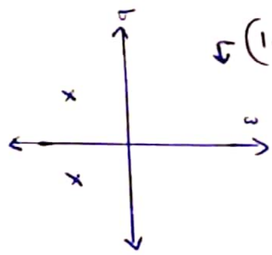
(1 mark)



(2 marks) c) High K_p (response should have oscillations)



(1 mark)



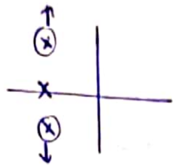
For each case, draw the expected location of the closed loop poles (roots of the homogenous part of the differential equation modelling the closed loop system).

([2+2+2+1+1+1] = 9 marks.)

2. As you increase K_p does the response become unstable (i.e. does the amplitude of the response grow without bounds?)? Where are the closed loop poles in this case according to the model? Try to explain the simulated behaviour that you see in this case.

No, the response is stable as the oscillation are bounded.
Even though the oscillation amplitude increases. ↳(1 mark)

[1+1+1 = 3marks]

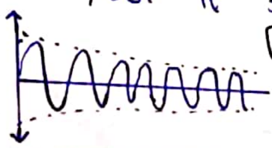


→ The poles go up and down respectively as kp increases. (1 mark)

The simulated behaviour shows that oscillation amplitude increases with increase in kp, but remains bounded and takes more time to settle down as kp increases. → (1 mark.)

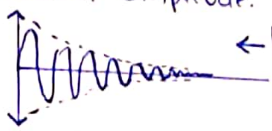
3. Based your responses above, comment on the accuracy of the model we have built for this example in class.

The model here is inaccurate because a lot of approximations are made, also the inaccuracy can be clearly seen at high values of kp, the arm angle response should have died down with time, but it seen to move with constant amplitude.



← Observed plot

$\theta(t) = \theta_{ss} + (\theta_0 - \theta_{ss}) e^{-\sigma t} \cos(\omega_d t)$ ↳



← Expected plot

4. Ask the TA about the definition of rise time, settling time and %OS (Over shoot). Pick a K_p that meets:-

[Rise time < 1.3 seconds, % OS < 25% and settling time < 8 seconds.]

kp → around (0.1 → 0.2)

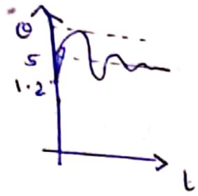
↳[2 marks]

B. Position Control - Proportional + Derivative Control (Turn off disturbance)

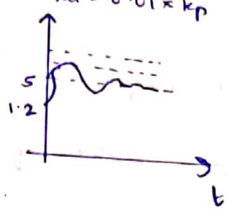
1. How does K_d affect the response: Fix K_p to the value chosen in A.4 above? Now change K_d and draw the responses progressively as you change K_d from ($0.001*K_p$) to ($1000*K_p$). Which one provides the best response in terms of rise time, settling time and % OS.

[4 marks]
↓
For plots and best response kd value.

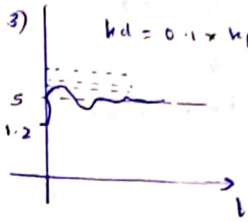
1) kd - 0.001 kp



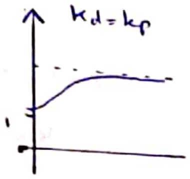
2) kd = 0.01 × kp



3) kd = 0.1 × kp

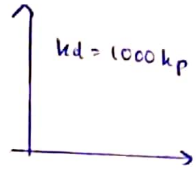


4) kd = kp



5) kd = 10kp

6) kd = 1000 kp



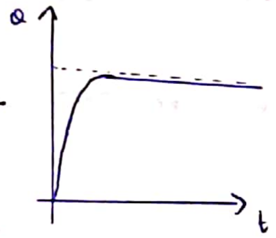
→ no movement of arm

When kd → (0.1kp to kp) → gives the best response

2. What if both K_p and K_d are free for you to choose? Try to get a rise time < 0.4 sec and 0 % OS. Can you do better than these specifications? Try to get a rise time < 0.35 sec, settling time

[2marks] ←

[2+1 = 3marks]



Yes, it is possible to have better values than the specified ones.
↳ [1 mark]
[kp and kd and specifications can differ]

C. Speed Control - Proportional (Turn off disturbance - increase the viscous friction coefficient for the (motor + load) block to 0.01 Nm/rad/s)

1. Set up the speed control (proportional only) feedback loop to track a constant 10 rad/sec arm rotational speed.

↳ no evaluation.

2. How does the Steady state error (SSE) change with K_p?

↳ SSE decreases with increase in kp, but SSE cannot be made zero with only increase in kp.

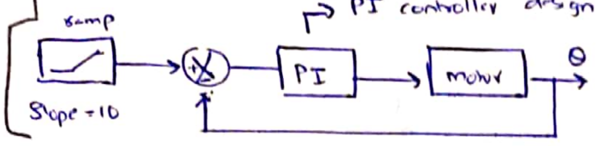
↳ [2 marks]

[7 marks]

3. Design a PI controller to reduce the SSE to zero. For your choice of K_p and K_I what is the %OS in the error signal and the settling time? Try reducing the %OS and settling time while maintaining the SSE to be zero. Report the final design that you get in this case and draw the corresponding plot of the error signal vs time.

→ PI controller design [2 marks]

2 [marks] →



k_p, k_i design → either through integrator, gain block or using direct PI block.

[2 marks] → kp and ki can differ

k_p, k_i → %OS

$t_{settling}$ (2%)] → value depends on chosen k_p, k_i

SSE

As k_i is finite, SSE → 0,

as kp increases, settling time decreases.

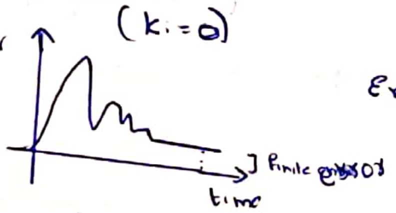
As ki increases SSE = 0.

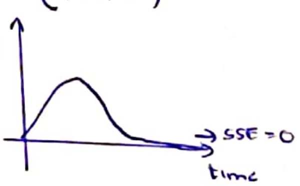
[2 marks]

The Final design.

↳ Block diagram shown above, should be shown.

[1 mark] Error vs time





[2 + 2 + 2 + 1 = 7 marks]

D. From what you learnt in this course - write in less than 100 words each:

1. For you, what seems to be the most interesting aspect of controls? 1.5 marks

2. For you, what seems to be the most non-interesting/boring aspect of controls? 1.5 marks

[Give full marks, if the student attempts the question]

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