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KON 326E
COMPUTER CONTROLLED SYSTEMS
PROJECT – 3

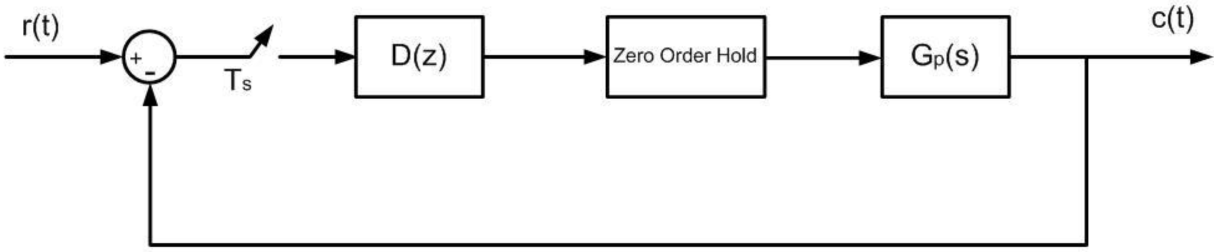
1. $G_p(s) = \dfrac{K\,e^{-T_d s}}{\tau s + 1}$, K=0.6, T_d=80 ms, τ = 300 ms and the sampling period T_s=20 ms are given for the system shown in the figure below. Investigate the change of the closed loop system poles (root locus) for the cases below:

a) $D(z) = K_c$

b) $D(z) = K_c(z - A)/(z - 1)$ where A is one of the poles of the discrete open loop transfer function.

c) Using the controller obtained in (b) determine the value of the parameter K_c to avoid overshoot. Calculate the closed loop transfer function for this value of K_c.

d) Simulate the system for various values of the gain K_c and plot the discrete system responses. Interpret the results that you obtained.



2. In this question a control system will be designed for a cargo ships' steering angle. Proposed controller has to be a discrete time controller. Continuous time model of the system is $G_p(s)$ and this 2nd order model is given as:

$$G_p(s) = \frac{\phi(s)}{\delta(s)} = \frac{0.185(18.5s+1)}{s(120s+1)(7.7s+1)}$$

Here $\delta(s)$ is the input angle and $\varphi(s)$ is the actual steering angle. Both of these angles can be assumed as radian or degree.

<u>Do the followings:</u>

a. Design a discrete-time (digital) controller to satisfy the design requirements given below. Determination of the sampling time must be considered as a part of the design.

Design Requirements (Specifications):

- Settling time of the steering angle must be less than 100 seconds when the reference input is unit step.
- Overshoot of the steering angle must not exceed %20 when the reference input is unit step.
- Steady state error must not exceed 0.75 when the reference input is unit step.
- Controller must be determined considering the above requirements. But you should also consider the magnitude of the control sign. Control signals with large magnitude **are not** preferred in practice.

a.1 Explain that how you determined the sampling period.

a.2 Can *a discrete time PD controller* satisfy all the design requirements? Why?

a.3 Explain the *controller structure* (for instance P,PI,PD,PID, cascade etc.) that you selected to apply mentioning the reasons.

a.4 Can *the controller that you designed* reject step disturbances or not? Why?

a.5 Simulate the whole system and verify that the designed controller satisfies all the requirements given above. Run your simulations for different (various) reference signals and give the graphics of the obtained responses.

a.6 While simulating the system in MATLAB Simulink use a "Saturation" block between the controller and the system. Assign the lower and upper bounds of the control sign as $-2.5 \leq u \leq 2.5$ and then redo your simulations. Verify that the designed controller satisfies all the requirements given above.

b. Plot the discrete time frequency response of the *open loop system* (Controller + System). Determine the Phase and Gain Margins and interpret these results. Can you determine the stability of the system by considering the Gain and Phase Margin?

c. Plot the discrete time frequency response of the *closed loop system*. Determine the frequency domain criteria and interpret these results.

d. Determine the difference equation for the discrete time controller that you designed in the first part of the question. Write the related MATLAB function for this difference equation. Redo your simulations replacing the controller block with "Interpreted MATLAB Fcn" block in Simulink. (Here you must call your difference equation function from the Interpreted MATLAB Fcn block)