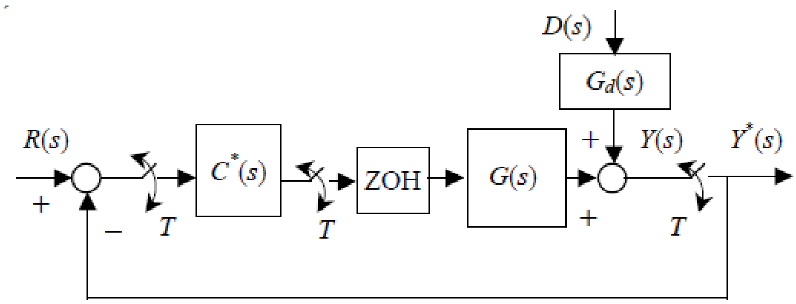
(10 points) Find the equivalent sampled impulse response sequence and the equivalent z-transfer function for the cascade of the two analog systems with sampled input

$$H_1(s) = \frac{1}{s+6} \qquad H_2(s) = \frac{10}{s+1}$$

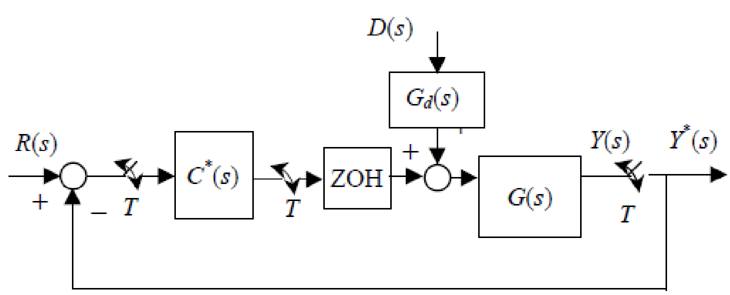
(a) If the systems are directly connected.
(b) If the systems are separated by a sampler.

(20 points) Find the steady-state response due to a unit step disturbance input for the systems shown in the following figures (a) and (b).

$$G_d(s) = \frac{2}{s+1} \qquad G(s) = \frac{4(s+2)}{s(s+3)} \qquad C^*(s) = \frac{e^{sT} - 0.95}{e^{sT} - 1}$$



(a)



(b)

(20 points) Consider the internal combustion engine model of Problem 3.5. Assume that, for the operational conditions of interest, the time constant τ is approximately 1.2 s while the parameter ε can vary in the range 0.4 to 0.6. The digital cascade controller

$$C(z) = \frac{0.02z}{z-1}$$

was selected to improve the time response of the system with unity feedback and a sampling period of 4 ms. Simulate the digital control system with $\varepsilon = 0.4, 0.5, 0.6$, and discuss the behavior of the system in each case (discuss the effects on the output of the system with respect to the location of the zero of the plant).

(20 points) Use the Routh-Hurwitz criterion to find the stable range of K for the closed-loop unity feedback systems with loop gain

(a) $G(z) = \dfrac{K(z-1)}{(z-0.1)(z-0.8)}$

(b) $G(z) = \dfrac{K(z+0.1)}{(z-0.7)(z-0.9)}$

(20 points) In many applications, there is a need for accurate position control at the nanometer scale. This is known as **nano-positioning** and is now feasible due to advances in nanotechnology. The following transfer function represents a single-axis nanopositioning system

$$G(z) = \frac{4.29\times10^{10}(s^2+631.2s+9.4\times10^6)(s^2+638.8s+45\times10^6)}{(s^2+178.2s+6\times10^6)(s^2+412.3s+16\times10^6)(s^2+209.7s+56\times10^6)(s+5818)}$$

a) Obtain the DAC-analog system-ADC transfer function for a sampling period of 100 ms and determine its stability using the Nyquist criterion.
b) Obtain the DAC-analog system-ADC transfer function for a sampling period of 1 ms and determine its stability using the Nyquist criterion.
c) Plot the closed-loop step response of the system of (b) and explain the stability results of (a) and (b) based on your plot.

(10 points) Describe how you would set up an experiment to characterize one of the DC motors we will be using for the midterm project. How would you determine a good sampling period for this system (assume that you will be printing information onto the screen at the rate of 115200 bps, and the maximum velocity on this type of motor is 3000 rpms)?