Problem 1: (70 points)

Figure 1 shows a simplified diagram of the attitude control of a satellite.

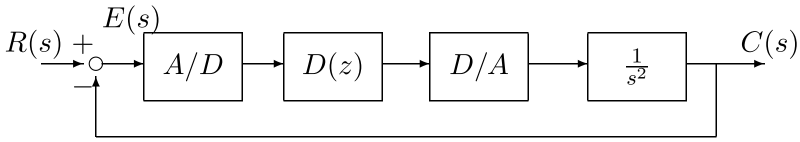

Figure 1: Simplified diagram of a satellite digital attitude control

1.1- (10 pts) Assume that $D(z) = K > 0$ and that the sampling time is $T > 0$. Find the steady–state error to a step input as a function of K.

1.2- (10 pts) Can you find a value of K such that the following performance specifications are satisfied?

1.2-a Zero steady state error to a step input

1.2-b No overshoot in the step response

If so, give a suitable value for K, if not, fully justify you answer. A simple yes or no answer will not give you partial credit.

1.3 (30 pts) Find a digital controller $D(z)$ such that the closed loop system achieves the performance specifications listed in part [1.2] and in addition has settling time to a step input $T_s \leq 4T$, where T denotes the sampling interval. Justify your design by drawing a Root Locus of the compensated system. Note: for this part do not worry about having a physically realizable controller.

1.4 (20 pts) We want to consider now the effects of time delays. To this effect, replace the plant $\frac{1}{s^2}$ by $\frac{e^{-sT}}{s^2}$, where the factor e^{-sT} models the time it takes for the actuators to react. Briefly explain the effects of this delay. Substantiate your answer by sketching a rough Root Locus plot for the closed loop system incorporating this delay.

Problem 2: (80 points)

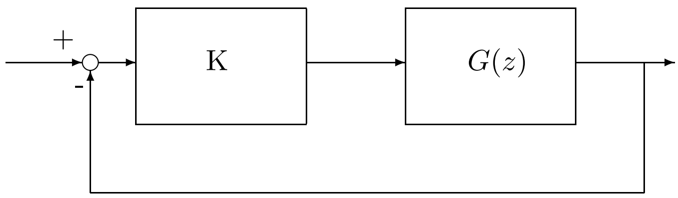

Figure 2

Consider the system shown in Figure 2. Assume that $D(z) = K > 0$ and that $G(z)$ is one of the following plants:

$$\frac{z+1}{z-1}, \tag{1}$$

$$\frac{(z+1)}{(z-1)^2} \tag{2}$$

$$\frac{(z+1)(z-\frac{1}{3})}{(z-1)^2}, \tag{3}$$

$$\frac{(z-1)}{(z+z_p)}, \; 0 < z_p < 1 \tag{4}$$

2.1 (40 points) For each of the plants above indicate which of the following performance specifications are achievable by selecting an appropriate value of the gain $K > 0$:

(a) Zero steady state error to a step input

(b) Zero steady state error to a ramp input

(c) Non oscillatory step response

(d) Settling time to a step input $T_s = T$

In order to get credit, you must fully justify your answer. A simple set of answers like $(1) \rightarrow (a), (b)$ without justification will not give you partial credit.

2.2 (40 points) For each of the plants above indicate what type of compensation must be used (if any) to achieve (simultaneously) all of the performance specifications. Justify your answer by sketching a rough Root Locus plot in each case. If for a given plant you cannot meet all the specs simultaneously, explain why and indicate which compensation should be used to achieve as many as you can.