# Design Project, ECE 421, Spring 2005
## Pitch Mode Control for a Small Aircraft
### Due 5:00 p.m., Wednesday, May 18

*A. Introduction*

This design project is to be an individual effort for each of the students. The George Mason University honor code applies to this project. Any questions concerning the project should be directed to Dr. Beale. Suspected violations of the Honor Code will be reported.

The goal of the project is to design a compensator to stabilize and provide adequate performance for the pitch mode dynamics of a small, single engine aircraft. The plant model is described by the transfer function

$$G_p(s) = \left.\frac{Y(s)}{U(s)}\right|_{D(s)=0} = \frac{-160\,(s+2.5)\,(s+0.7)}{(s^2+5s+40)\,(s^2+0.03s+0.06)} = \left.\frac{\theta(s)}{\delta_e(s)}\right|_{D(s)=0} \qquad (1)$$

where the system output $Y(s)$ is the pitch angle $\theta(s)$ in degrees and the control input to the plant $U(s)$ is the elevator angle $\delta_e(s)$ in degrees. Note the sign of the gain in the numerator. The pitch angle is the angle between a horizontal axis and the longitudinal axis of the aircraft, with positive pitch being upward. The elevator angle is the deflection angle of a movable control surface on the aircraft relative to the longitudinal axis of the aircraft. As indicated by the negative sign in the numerator of (1), a positive deflection of the elevator angle produces a negative pitch angle.

The compensator $G_c(s)$ will be placed in series with $G_p(s)$ in the normal unity feedback, closed-loop configuration. The reference input $R(s)$ is the desired value for the pitch angle (in degrees), that is, $R(s) = \theta_{desired}(s)$. The pitch error $E(s) = \theta_{error}(s)$ is the difference between the desired and actual pitch angles.

*B. Specifications*

The following specifications are imposed on the response of the compensated closed-loop system to a step change in the reference input signal with no disturbance:

1. The steady-state value of the pitch error must not exceed 10% of the magnitude of the step input.
2. The overshoot in pitch angle must not exceed 20% of the final value of the angle.
3. The settling time for the pitch angle must not exceed 12 seconds.
4. The maximum absolute value of the elevator angle must not exceed 15% of the magnitude of the step input.

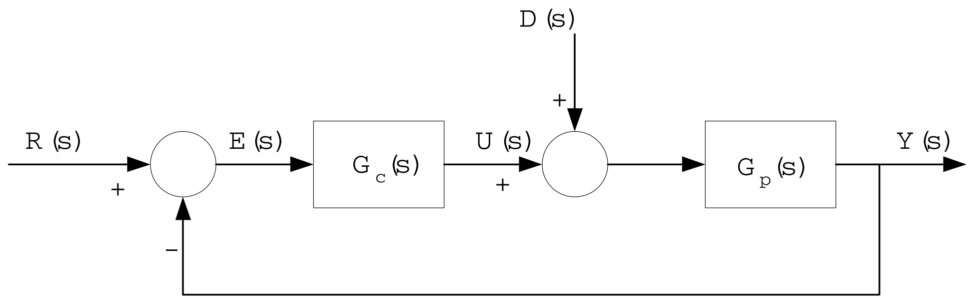


Fig. 1. System block diagram for pitch mode control of a small aircraft.

*C. Tasks*

1. Design a compensator $G_c(s)$ such that all specifications are satisfied. The compensator transfer function must be proper, and there can be no unstable pole/zero cancellations between the plant and the compensator.
2. With $D(s) = 0$, perform simulations in MATLAB to verify that your design is acceptable. Plots must be made that indicate the responses of the various signals are satisfactory. These plots must include the root locus for both the uncompensated and compensated systems, the pitch angle (output) step response for the compensated system, and the elevator angle (control signal) step response for the compensated system. Also, include the closed-loop step response of the pitch angle for the uncompensated system, that is, with $G_c(s) = -1$.
3. Develop a SIMULINK model corresponding to Fig. 1. Simulate the compensated system under each of the following 4 conditions. Plots of the output signal must be provided for each of the conditions. Plots for the first two conditions should be on the same graph, and plots for last two conditions should be on the same graph. Also include the SIMULINK diagram for your system in the report.
   a. The disturbance signal is 0, and the reference input signal is a step function of amplitude 10 degrees.
   b. The disturbance signal is a step function of amplitude 0.1 degrees applied at $t = 8$ seconds, and the reference input signal is a step function of amplitude 10 degrees.
   c. The disturbance signal is 0, and the reference input signal is a ramp function with a slope of 0.5 deg/sec.
   d. The disturbance signal is a step function of amplitude 0.1 degrees applied at $t = 8$ seconds, and the reference input signal is a ramp function with a slope of 0.5 deg/sec.

### *D. Report*

You must provide a typed report that documents your design activity and provides plots that verify that all the specifications are satisfied. Handwritten reports will not be accepted. If you wish, you may produce your reports, including plots, in the form of web pages rather than in hardcopy form. In that case, you must provide me with the URL for your web pages by the time that the project report is due.

Your report must describe your design approach and explain how the approach is able to satisfy the design specifications. Your report must reference each of the plots that are included in it. The plots must clearly demonstrate that the specifications are satisfied, and the plots must be clearly labeled with axis labels and titles.

In your report, discuss the improvements in performance provided by your compensator relative to the uncompensated system. Also discuss the effects of disturbances on the step and ramp responses of the compensated system as seen in the SIMULINK plots. Compare the ease of using SIMULINK to produce simulation results relative to performing the simulations directly in MATLAB.