ELEC ENG 4CL4 – CONTROL SYSTEM DESIGN

Lab #4: Analysis of control design limitations and remedies within MATLAB/Simulink

Objectives:

To gain experience in controller design within MATLAB/Simulink, including controller synthesis, analysis of fundamental limits in SISO control, and remedies for such limitations.

Assessment:

Your grade for this lab will be based on your ability to apply controller-synthesis methods to achieve certain performance requirements and create Simulink models to analyse fundamental limits and introduce remedies in controlling the plant model described below, and on your reporting of the results. The report should contain the results of your pre-lab derivations and calculations, schematics of your Simulink models with brief descriptions, MATLAB plots of results with brief descriptions, and answers to specific questions below.

The total grade will be out of 20 points. The written report will be worth 15 points, and the remaining 5 points will be based on your demonstration of your Simulink model and MATLAB code to the TA and/or a pre-lab quiz on the theory required for this lab.

Clearly label all plots and their axes (points for style will be deducted otherwise)

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Please attend the lab section to which you have been assigned.

You should complete this lab with one lab partner. If there are an odd number of students, then one group of three will be created by the TA, or you can choose to work on your own if a computer is available.

You may choose to complete the lab assignment partially or entirely in your own time (in groups preferably of two students but definitely no larger than three). However, if you choose to do this, you must show up at the start of your scheduled lab time to give the TA a brief demonstration of your MATLAB/Simulink code and model.

Each pair of students should complete one lab report together, which is to be submitted one week from the date of the lab.

1. Pre-lab:

The dynamics of an elevator can be described by the nominal model:

$$G_o(s) = \frac{1}{s^2 + 12s + 16},$$

where the plant input $u(t)$ is a control signal to the elevator's motor and the plant output $y(t)$ is the vertical position of the elevator in the elevator shaft. Two design constraints need to be considered:

i. This elevator is known to be regularly subject to low-frequency (< 4 rad/s) output disturbances due to passengers entering and exiting the elevator and moving about while within it.

ii. The nominal model is known to be accurate only at low-frequencies (< 4 rad/s)—above 4 rad/s the multiplicative modeling error grows large.

a. Use the pole-assignment method to synthesize a controller $C(s)$ that will reject the output disturbances described above while maintaining stability in the face of the known modeling errors, also described above.

Hint: The easiest thing to do is place all the closed-loop poles at the same location on the s-plane.

b. Does the resulting nominal complementary sensitivity function $T_o(s)$ have any zeros closer to the imaginary axis of the s-plane than the closed-loop poles? If so, the controller synthesised above will produce overshoot in response to a step reference. To remove the overshoot, a reference prefilter can be designed and implemented in a two-d.o.f. architecture. The prefilter $H(s)$ should cancel any of the offending zeros in $T_o(s)$ and should have a DC gain of 1.

2. Frequency response for reference and output disturbance changes

a. In Simulink, place the nominal plant model given above in a one-d.o.f. unity-feedback loop with the controller designed in the pre-lab.

b. Find the plant output $y(t)$ for sinusoidal *reference signals* with various frequencies within the range of 10^{-1}–10^{2} rad/s. Use these results to generate a plot of the approximate magnitude-frequency response for reference changes.

c. Find the plant output $y(t)$ for sinusoidal *output disturbances* with various frequencies within the range of 10^{-1}–10^{2} rad/s. Use these results to generate a plot of the approximate magnitude-frequency response for output disturbances.

d. Do these two magnitude-frequency responses (from parts b and c) indicate that you have met the design criteria described in the pre-lab description above? Explain.

3. Responses to ramp reference changes

It is desired for the elevator to be able to move from one floor to the next in 3 seconds with relatively constant velocity (i.e., a ramp reference change). This can be achieved via a piece-wise linear reference signal, as illustrated in Fig. 1, which can be generated via the "Repeating Sequence" Simulink block.

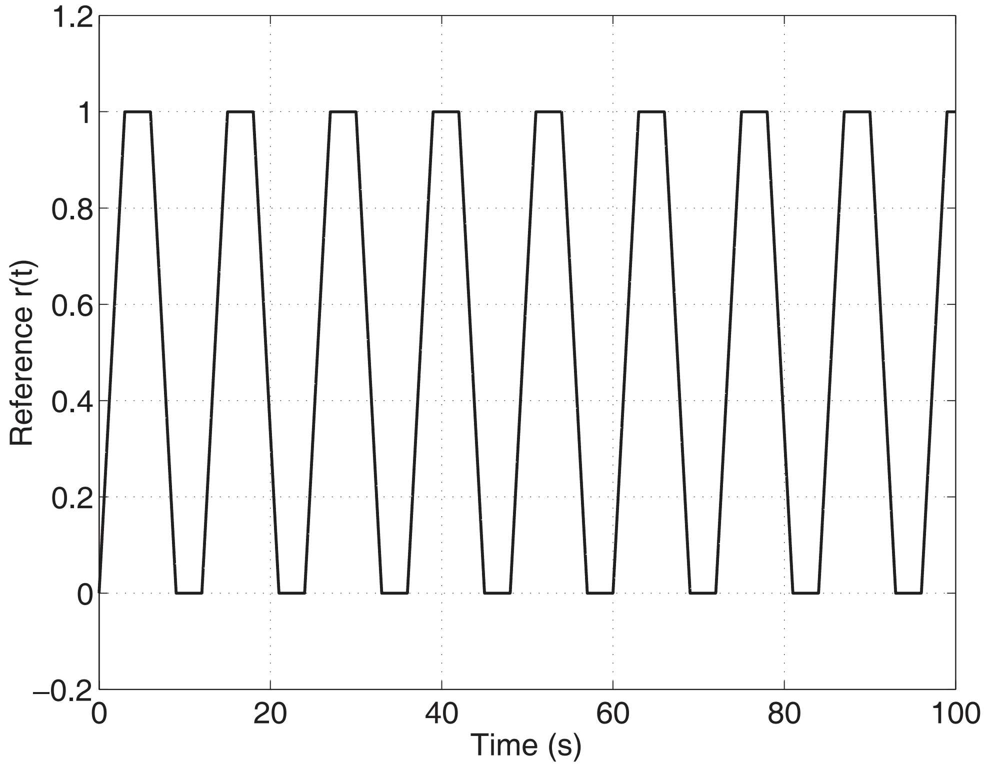

Figure 1

a. Plot the plant input $u(t)$ and output $y(t)$ to such reference changes.

b. Do the plant input and output for such reference changes indicate possible problems for the elevator's motor and the passenger's stomachs, respectively? If so, why?

c. Extend the control loop to a two-d.o.f. architecture using the reference prefilter $H(s)$ designed in the pre-lab.

d. Show what effect prefiltering the reference has on the plant input and output.

e. Has it remedied the problems reported in part b above? If so, what is the penalty in terms of travel time from one floor to the next?

f. Would it be preferable to just relax the travel-time requirement and leave out the reference prefiltering? Show why or why not.

g. Show what effect adding the reference prefilter has on the system's response to output disturbances. Is this expected?