**Automotive Control Systems (EE 5812/MEEM 5812)**
**Project #6**
**Active Suspension Design**
**Submit: Your report in Canvas in pdf format, your script for designing the controller as an m-file, your final Simulink Controller as a slx-file**

Someone (who shall remain nameless) designed a very poor passive suspension system. Luckily, a force actuator was included in the suspension system design. Therefore, active feedback (an active suspension system) can be used to fix the suspension problems.

I have supplied a quarter car simulation and road profiles in the Canvas assignment as a file "ActiveSuspensionSim.slx" This file also contains a controller subsystem block. The empty controller subsystem is included as "ActiveSuspensionController.slx"

The inputs to the controller are the suspension stroke and passenger compartment acceleration. The output of the controller block is the force supplied by the force actuation. Your job will be to populate the controller block such that you achieve good suspension system performance.

There are three m-files also included in the assignment on Canvas: "ActiveSuspensionParameters.m" "ActiveSuspensionMenu.m" and "ActiveSuspensionAutoGrading.m" These three files should be downloaded. The five downloaded files should all be put in the active Matlab folder for the simulation to run.

The quarter car model is discussed in class. This model is given as a state model in the Simulink simulation. The states definitions of the model in Simulink match the state definitions given in the class notes.

1. Run the model with each of the four inputs and zero active control. Plot the suspension stroke the tire deflection ($Z_{us} - Z_0$), the passenger compartment acceleration ($\ddot{Z}_s$), and the force (f). There is a scope for displaying these variables. Include these plots at the start of your report. Comment on the performance when not using active control. Ignore the pop up window that give you credit when running the baseline system (no active control).

2. Design an active suspension system for this vehicle. Use LQR for generating a state feedback controller as discussed in the class notes. Use an observer to estimate the states of the system. Set the observer poles to be four times the state feedback poles. Your controller should meet the following specifications.

For the ramp input:

The settling time should be less than 2.2 seconds. This is computed by observing how long it takes for the suspension stroke to stay within 2% of the maximum negative excursion.

The % Overshoot should be less than 12%. This is computed by observing how large is the positive overshoot compared to the maximum negative excursion.

The maximum magnitude of the suspension stroke should be less than 0.12 m.

The maximum magnitude of the tire deflection should be less than 0.03 m.

The maximum magnitude of the passenger compartment acceleration should be less than 0.2 $m/s^2$.

The maximum magnitude of the applied force should be less than 5,000 N.

For the sinusoidal input:

The steady state amplitude of the suspension stroke should be less than 0.12 m.

The steady state amplitude of the tire deflection should be less than 0.03 m.

The steady state amplitude of the passenger compartment acceleration should be less than 2 $m/s^2$.

The steady state amplitude of the applied force should be less than 5,000 N.

For the rectified sinusoidal input:

The maximum magnitude of the suspension stroke should be less than 0.12 m.

The maximum magnitude of the tire deflection should be less than 0.03 m.

The maximum magnitude of the passenger compartment acceleration should be less than 2 $m/s^2$.

The maximum magnitude of the applied force should be less than 15,000 N.

For the random input:

The maximum magnitude of the suspension stroke should be less than 0.12 m.

The maximum magnitude of the tire deflection should be less than 0.03 m.

The maximum magnitude of the passenger compartment acceleration should be less than 2 $m/s^2$.

The maximum magnitude of the applied force should be less than 5,000 N.

3. Provide short answers to the following questions:

   1. Is the suspension stroke, the tire deflection, the passenger accelerations, and the applied force reasonable? Why?

   2. Comments on how changing the cost function weight on the suspension stroke effects the control performance.

   3. Comments on how changing the cost function weight on the tire deflection effects the control performance.

   4. Comment on how changing the cost function weight on the control changes the performance.

   5. Comment on how the performance of the observer?

Generate a very brief report that consists of the controller design, the plots obtained with zero control, and the plots obtained with your final controller. Upload your report in Canvas as a pdf file. Upload your script for generating the control as an m-file. Upload your final controller as a slx-file.

Comments:

Each student should do this project individually and no student should share Simulink diagrams or code or results with other students. Note that I will be running your results through a similarity checker. If you have shared results and it is detected, you will fail this course! So, please don’t share code. But, feel free to ask your instructor questions or check results with your instructor.