**ECE-521** Control Systems II
Homework 4

**<u>Due Date:</u>** Tuesday April 27

Note: For any problem you use Matlab and/or Simulink on, I want you to turn in your Simulink model and the Matlab driver.

$\boxed{1}$ The Simulink model file **state_variable_a.mdl** with it's Matlab driver **sv_a_driver.m** simulates the state variable system

$$\begin{aligned} \dot{\underline{x}}(t) &= \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 6 & -1 & 1 \end{bmatrix} \underline{x}(t) + \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} u(t) \\ y(t) &= [1\ 0\ 0]\,\underline{x}(t) \end{aligned}$$

with state variable feedback form

$$u(t) = Fr(t) - K\underline{x}(t)$$

with the closed loop poles at $-3 \pm 3j$ and $-10$.

a) Run the simulation as it is, and save the plot to turn in.

b) Create a Simulink model (and Matlab driver) to implement the control system depicted in Figure 12-6 (for a type 0 plant). Place the new pole at -3. Using **subplot**, plot the three states from the original implementation (part a) and the corresponding three states from the new implementation on the same graphs (both $x_1$'s on the same graph, both $x_2$'s on the same graph, and both $x_3$'s on the same graph, be sure to use the **legend** command and different line types so I can tell which graph came from which simulation.)

c) Now change the value of the new pole (make it more negative). At what value of pole location do the two different simulations produce the same response?

d) Now we'll explore why one might use the implementation model. Rerun the models and this time (with the new pole set back to -3), assume $F$ has changed by 50% (multiply $F$ by 1.5) and assume $k_l$ has also changed by 50%. Plot the results as you did in part b. Can you see why we want an integrator and why we want everything inside the closed loop? (Remember we want $y = x_1 = 1$ in steady state.) What happens if the location of the new pole is changed?

$\boxed{2}$ In this problem we will explore the configuration of the type 1 plant (Figure 12-4) and compare the results to our normal feedback system for the model

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\begin{aligned}
\dot{\underline{x}}(t) &= \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \underline{x}(t) + \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} u(t) \\
y(t) &= [1\ 0\ 0]]\underline{x}(t)
\end{aligned}
$$

with state variable feedback form

$$
u(t) = Fr(t) - K\underline{x}(t)
$$

with the closed loop poles at $-3 \pm 3j$ and $-10$.

a) Modify the Matlab code **sv_a_driver.m** for this new system, run the simulation for about 5 seconds, and print out the output.

b) Create a Simulink model (and Matlab driver) to implement the control system depicted in Figure 12-4 (for a type 1 plant). Using **subplot**, plot the three states from the original implementation (part a) and the corresponding three states from the new implementation on the same graphs (both $x_1$'s on the same graph, both $x_2$'s on the same graph, and both $x_3$'s on the same graph.) The graphs should be on top of one another.

c) Now we'll explore why one might use the implementation model. Rerun the models and this time, assume $F$ has changed by 50% (multiply $F$ by 1.5) and assume $k_l$ has also changed by 50%. You will probably need to let the simulations run for about 10 seconds. Plot the results as you did in part b. Can you see why we want an integrator and why we want everything inside the closed loop? (Remember we want $y = x_1 = 1$ in steady state.)

$\boxed{3}$ Problem B-12-19 from the textbook. You should write out the equations to be solved, and then use Maple to find all possible solutions. Determine the eigenvalues for each possible $P$ matrix. (*Ans. 3 possible $P$ matrices*, $u(t) = -x_1 - x_2$)

$\boxed{4}$ Problem B-12-20 from the textbook. Do no use Maple or Matlab (except to check yourself). ($Ans. u = -x_1 - \sqrt{\mu + 2x_2}$)

$\boxed{5}$ Problem B-12-21 from the textbook. Use Simulink (with a Matlab driver) for the regulator problem, and use **subplot** to put all plots on one page (do not put them all on one graph). Run the simulation for 10 seconds.