LAB2: **Time responses of first order and second order systems**

And effect of poles and zeros

Objectives:

- To design simulink models to investigate the time responses of first order and second order systems.
- The effect of zeros and additional poles on a system.

Pre lab: (by Hand)

- What is the transfer function for a standard second order system?(in terms of ωn & ς)
- Determine the location of the poles for each of the following eight scenarios:

a) ωn = 2, ς = –1 , b) ωn = 2, ς = 0 , c) ωn = 2, ς = 1/10 , d) ωn = 2, ς = ¼ ,
e) ωn = 2, ς = 1/2 , f) ωn = 2, ς = 5/4 , g) ωn = 1, ς = ¼ , h) ωn = 4, ς = ¼

- For a DC motor position control system, with load position denoted by $\theta_o(t)$ and voltage input by $e_a(t)$, the open loop transfer function is given by

$$\frac{\theta_o(s)}{E_a(s)} = \frac{0.2083}{s(s+1.71)}$$

Let $e_a = K(\theta_{desired} - \theta_o)$ where $\theta_{desired}$ is 50 degrees or 0.873 radians. Draw a block diagram for the feedback control system. Try to determine by trial-and-error, suitable values of K to drive $\theta_o(t)$ to its desired value in a stable fashion.

Background:

Simulation of Prelab problems

1) We will use the MATLAB to generate a simulation of the impulse response for each of the prelab scenarios. (or use plot_tf.m sent to you via email)
2) Use MATLAB's **SYS = tf(NUM,DEN)** to generate each transfer function.
3) To generate the impulse response use **impulse(sys)**
4) Replot the scenarios: ωn = 2, ς = 1/10; ωn = 2, ς = 1/4; and ωn = 2, ς = 1/2 on a *single plot*. What is the effect of ς?
5) Use MATLAB's **hold** to overlay the individual plots.
6) Replot the scenarios: ωn = 2, ς = 1/4; ωn = 1, ς = 1/4; and ωn = 4, ς = 1/4 on a single plot. What is the effect of ωn?

Example of a Second order system (Also check example 2.14 in the text)

A DC motor, whose electric circuit of the armature and the free body diagram of the rotor are shown in Fig. 1

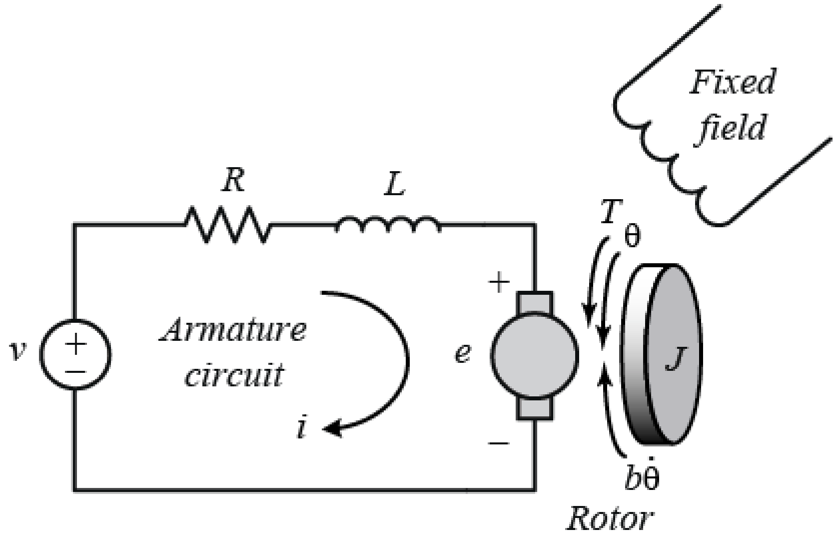

Figure 1: Schematic representation of an example DC motor

The rotor and the shaft are assumed to be rigid. The input is the armature voltage *v* in Volts (driven by a voltage source). Measured variables are the angular velocity of the shaft θ· in radians per second, and the shaft angle θ in radians.

System equations:

$$J\frac{d^2\theta}{dt^2}+b\frac{d\theta}{dt}=Ki$$

$$L\frac{di}{dt}+Ri=V-K\frac{d\theta}{dt}$$

Transfer function:

$$G(s)=\frac{\dot{\theta}(s)}{V(s)}=\frac{s\theta(s)}{V(s)}=\frac{K}{(R+Ls)(Js+b)+K^2}\quad\left[\frac{\text{rad/sec}}{\text{V}}\right]$$

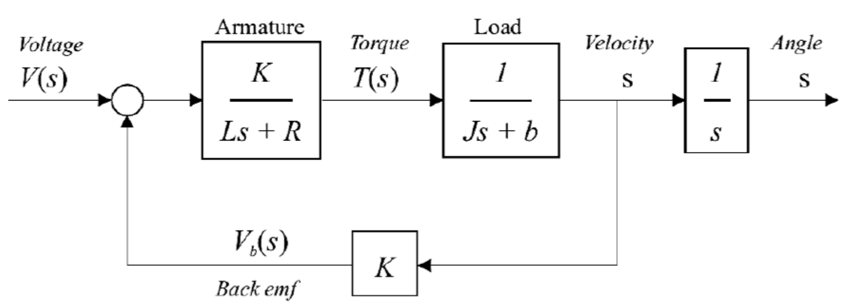

Figure 2: A block diagram of the DC motor

Please refer to *section 3.3* *for theory about effect of poles*

Reference for pole zero plots:

1) *https://en.wikipedia.org/wiki/Pole%E2%80%93zero_plot*
2) pzmap(sys) creates a pole-zero plot of the continuous- or discrete-time dynamic system model sys in MATLAB

To get Simulink model from system equations:

1) **http://ctms.engin.umich.edu/CTMS/index.php?example=MotorPosition&section=SimulinkModeling**
2) **http://vigir.ee.missouri.edu/~gdesouza/ece4310/index.htm**

Lab:

1. Reproduce the first order time response of Figure 3.16 ('natural response for various pole locations'). Also verify in Matlab.
2. Reproduce Fig. 3.19 (a and b; Responses of 2nd order system for various damping ratios). Also verify in Matlab.
3. Reproduce Figs. 3.27 and 3.36 (Effects of zeros and additional poles). Also verify in Matlab.

Lab Procedure:

1) Open the simulink 'Library Browser' by clicking on Start → Simulink. Open a new model file (.mdl). Build a model of the above closed loop system by using the respective blocks.
2) Double-click on the blocks to open its property editor. This will give you options of changing the parameters of the blocks.
3) Arrange the blocks in the proper order, and connect them.
4) Also save your workspace to mat lab.
5) Go to Simulation → Configuration Parameters. Set the Stop Time as needed.
6) Simulate the model and look at the output by double-clicking on the Scope.
7) Save the result for first order pole locations.
8) Save the result for second order pole locations.
9) Save the result for effect of zeros and additional poles.

❖ Also show the MATLAB PLOTS along with SIMULINK plots.

Post Lab: Write a report in Abstract, Objective, theory, procedure, results, conclusion and appendices. All steps should be clearly mentioned. Include all plots and results.