Project 1: Digital Control of DC Motor Speed

Lab objectives

- To

Equipment/Software needed per station

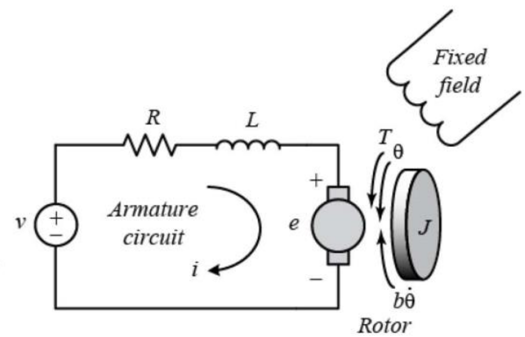
- MATLAB R 12 or higher.

Project

Consider the dc motor specifications, which we saw in Lecture 15.

Inertia J = 0.1
Friction coefficient b = 0.01
Torque constant K = 0.01
Armature resistance R = 1
Armature inductance L = 0.5
Sampling frequency fs = 10 Hz

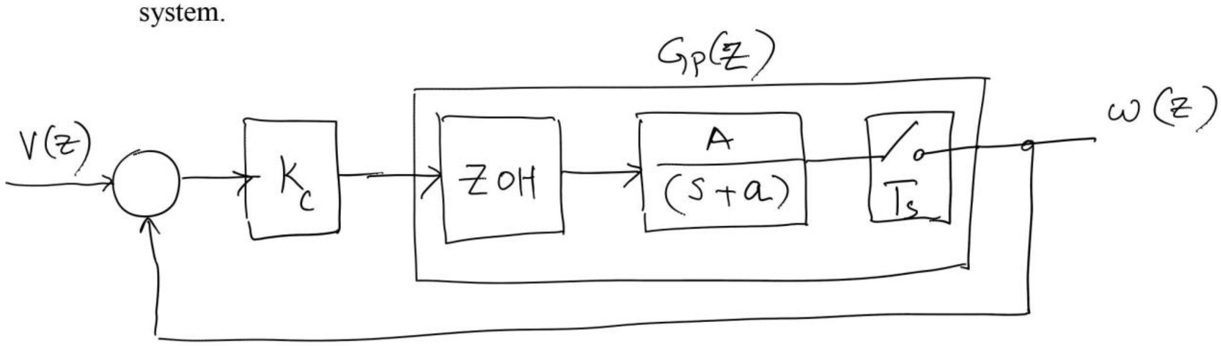
$$G(s) = \frac{\omega(s)}{V(s)} = \frac{K}{JLs^2+(bL+RJ)s+(bR+K^2)}$$



a) Plot the pole-zero map and predict the step response.
b) Calculate the steady-state value and the 2% settling time.
c) Plot the step response due to 1 V switched in at time t = 0.
d) Verify the steady state value and the 2% settling time from the plot of the step response.
e) Determine the dominant pole and the approximate first-order equivalent Laplace Transfer function:

$$G(s) \approx \frac{A}{s+a}$$

f) Plot and compare the step responses of the original and the approximate Laplace models. We will use this approx. first order model for designing the digital feedback control system.



g) Find the pulse transfer function $G_P(z)$ at a sampling frequency of 20 Hz. This is the open loop transfer function.
h) Plot the pole-zero map and plot the step response of the pulse transfer function.
i) Calculate the steady-state value of the motor speed using $G_P(z)$.
j) Find the proportional controller gain K_C for which the settling time is $1/10^{th}$ of that in the open-loop transfer function.
k) Using the value of K_C in step j) find the closed loop transfer function $G_C(z)$.
l) Plot the pole-zero map and plot the step response of the closed loop TF.
m) Calculate the steady state value of the response.
n) Plot the step response and verify the new 2% settling time.
o) Plot the dead beat response.

Some formulae:

First order digital systems

$$H(z) = \frac{k}{a_0 + a_1 z^{-1}}$$

The steady state value of response $y_{SS} = \frac{K(1-z)}{(1-p)}$ or $y_{SS} = \frac{k}{(a_0 + a_1)}$

Second order digital systems

$$H(z) = \frac{b_0 + b_1 z^{-1}}{a_0 + a_1 z^{-1} + a_2 z^{-2}}$$

The steady state value of response $y_{SS} = \frac{K(1-z_1)(1-z_2)}{(1-p_1)(1-p_2)}$ or $y_{SS} = \frac{(b_0 + b_1)}{(a_0 + a_1 + a_2)}$

First order continuous systems

$$H(s) = \frac{k}{a_0 s + a_1}$$

The steady state value of response $y_{SS} = \frac{K(-z)}{(-p)}$ or $y_{SS} = \frac{k}{a_1}$

Time constant $\tau = \frac{1}{abs(p)}$ 2% Settling Time $t_{\_02} = 4\tau = \frac{4}{abs(p)}$

Second order continuous systems

$$H(s) = \frac{b_0 s + b_1}{a_0 s^2 + a_1 s + a_2}$$

The steady state value of response $y_{SS} = \frac{K(-z_1)(-z_2)}{(-p_1)(-p_2)}$ or $y_{SS} = \frac{b_1}{a_2}$