LAB 5: SPEED CONTROL OF QNET DC MOTOR

1 Objectives

In this lab, we will design a controller for angular speed. We will use the identified transfer function of the QNET DC MOTOR in `lab-03` to design a controller that matches some desired perfermances. We will then use MATLAB to drive the QNET DC MOTOR and evaulate the designed controller.

2 The Open-loop System

2.1 Ressource files

Similary to previous labs, we provide a MATLAB class which interfaces with the QNET DC MOTOR.

1. Log in to `myCourses` and select the content folder Labs.
2. Download `lab_05_matlab.zip`.
3. Unzip the content in your MATLAB workspace.
4. Open MATLAB and navigate to the path where you have `Lab_05_SpeedControl.m`.
5. Run `Lab_05_SpeedControl.m`. You shouldn't have any errors, you will have warnings that you can ignore.

2.2 QNET DC MOTOR model

The general form of the transfer function between the rotor angular speed Ω and the input voltage V of a DC Motor (Figure 1) can be written as

$$H(s) = \frac{\Omega(s)}{V(s)} = \frac{K_t}{(Js+b)(Ls+R)+K_tK_e}$$

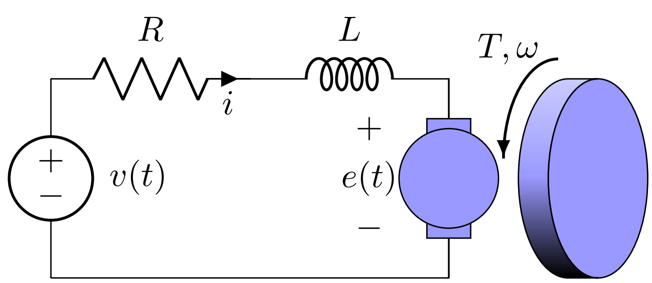

Figure 1 A schematic diagram of a DC motor

We have seen in `lab-03` that the QNET DC MOTOR transfer function can be approximated to a first order transfer function with DC gain G and time constant τ.

$$\frac{\Omega(s)}{V(s)} = \frac{G}{\tau s+1}$$

where $G = \dfrac{K_t}{bR + K_t K_e}$ and $\tau = \dfrac{JR}{bR + K_t K_e}$. The values of the G and τ might change from QNET DC MOTOR to another, however, we will use the following values for the controller design.

```
gain = 28.5;  % DC gain
tau = 0.16;   % Time constant
```

In `open-loop` form, we can represent the block diagram of this system as follow (Figure 2)

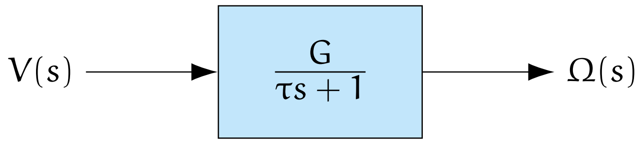

Figure 2 Block diagram of the open-loop system.

We can simulate the `open-loop` system in MATLAB by using `lsim`. For instance, in order to simulate the response to a defined voltage signal one can do:

```
dt   = 0.01;                  % Sampling time
T    = 10;                    % Duration of simulation
time = 0:dt:T;                % Define time vector
% Generate a voltage input signal
% equals 0 from [0 sec, 1 sec],
% equals 2 from [1 sec, 9 sec],
% equals 0 from [9 sec, 10 sec]
uSim = 0*(time<1) + 2*(time>=1 & time<T-1) + 0*(time>=T-1);
H = tf(gain, [tau 1]);       % Define the transfer function.
ySim = lsim(H, uSim, time); % Simulate the transfer function H.
```

2.3 Question 1

We want to drive the QNET DC MOTOR in the following square wave form Figure 3.

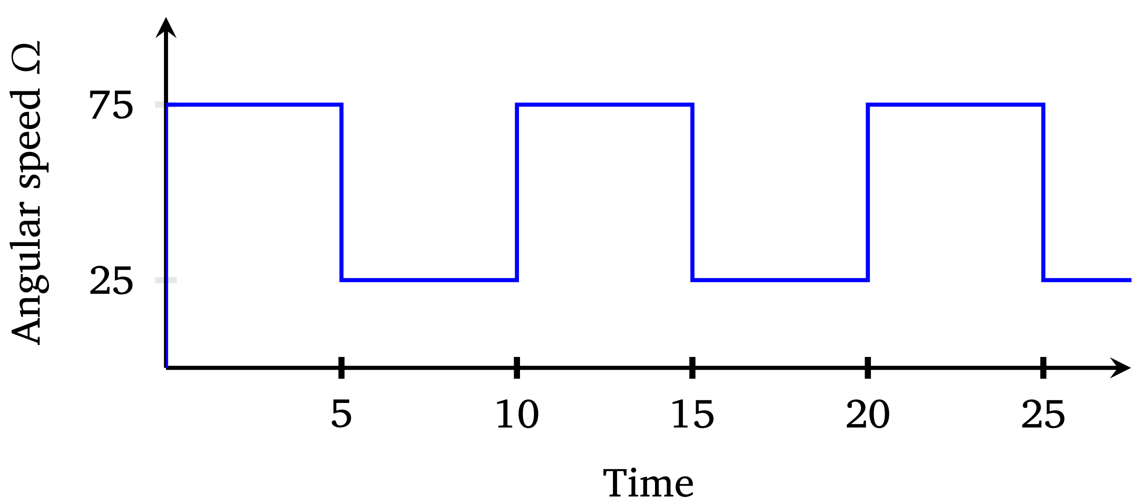

Figure 3 Square wave with frequency 0.1 Hz.

1. In MATLAB generate and plot a signal that mimics the shape of the square wave presented in Figure 3.
2. What is the value of the voltage V that you should input to the QNET DC MOTOR to get a steady-state angular speed of $\Omega = 25$? $\Omega = 75$?
3. Using these volage values, generate a square wave input signal that will make the QNET DC MOTOR follow the square wave form in Figure 3. Simulate and plot the response of the transfer function $H(s)$ to this signal.
4. Drive the QNET DC MOTOR with this square wave input signal. Superpose both the test results and the simulation results.
5. Discuss with your TA the following: Does the proposed model $H(s)$ satisfactory describes the QNET DC MOTOR ? Do we achieve satisfactory resluts with open-loop ? What if the frequency of the square wave was 5 times bigger ? (Include the discussion in the report).

3 Profile Tracking

3.1 Specifications

The objective of this section is to design a controller $K(s)$ that enable us to to track the square wave in Figure 4 with the following specifications:

- Steady-state error less than 5%.
- 5%-Settling time of 0.25 s.
- Overshoot less than 10%.

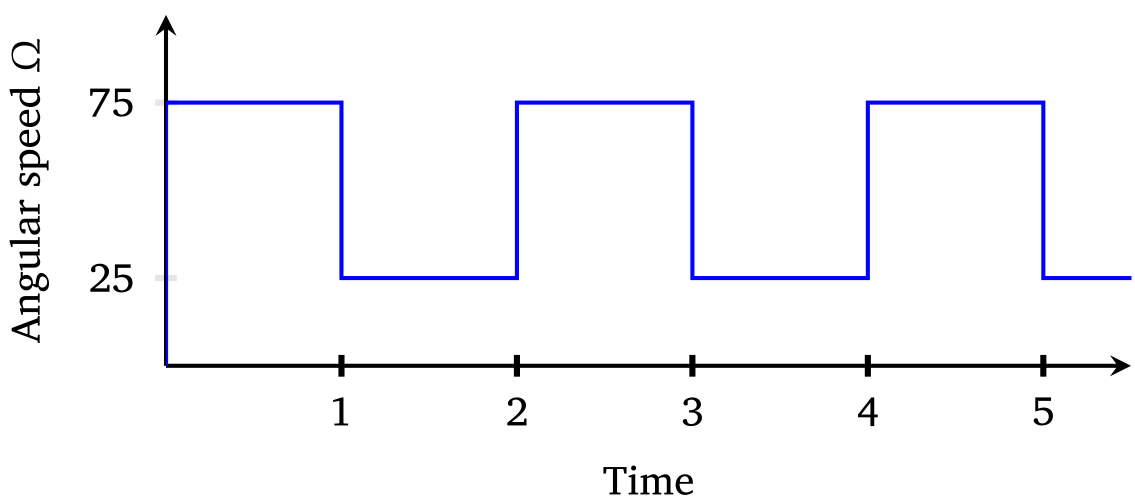

Figure 4 Square wave with frequency 0.5 Hz.

The controller $K(s)$ forms a unity feedback with the QNET DC MOTOR , Figure 5 shows the block diagram of the closed-loop system.

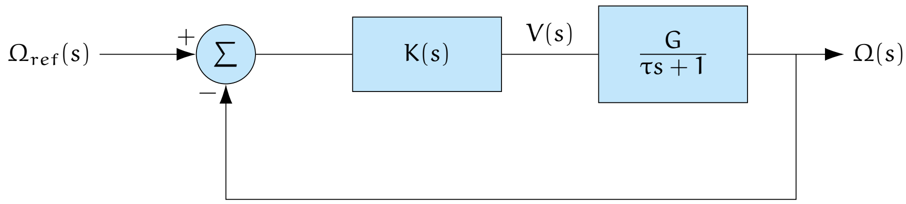

Figure 5 Block diagram of the closed-loop system.

3.2 Question 2: P-controller

First let's design a P-controller, i.e $K(s) = k_P$.

1. In MATLAB generate and plot a signal that mimics the shape of the square wave presented in Figure 4.
2. Write the closed-loop transfer function between the input Ω_{ref} and the output Ω.
3. Design a controller $K(s) = k_P$ that meets the specifications. Notice that for a first order system, the 5%-settling time (the time taken to get to 95% of the steady-state value and not oscillate after this time) is around 3 times the time constant.
4. In MATLAB simulate the system transfer function and plot both the output angular speed Ω and the voltage V.
5. Drive the QNET DC MOTOR in closed-loop with the P-controller that you have designed. Plot your results superposed with your previously simulated results. Did your controller work as expected ?
6. The QNET DC MOTOR have a voltage saturation of ± 5 V, by looking at the plot of the simulated voltage command, when does the voltage hits those saturations? Use the transfer function between the input $\Omega_{ref}(s)$ and command voltage $V(s)$ to give an upper-bound value of k_P that keeps the voltage between ± 5 V.
7. Use the maximum value of k_P to drive the QNET DC MOTOR . Plot your results superposed to simulated results.
8. What are the performance of this controller (Steady-state error, 5%-Settling time, Overshoot). How does these perfermances compare to the desired specifications.

4 Assignement

In a report format, answer the laboratory questions. The report should contain:

- An introduction and a conclusion, outlining the purpose of the laboratory and what you have learned.
- Explanation of the steps to answer the laboratory questions.
- All figures should have a legend and a caption.
- Include your code in the report appendix.

  The assignment is due 7 days after your lab.