EEE342 Feedback Control Systems - Laboratory Work 2
Bode Plot of DC motor's Transfer Function

Ezgi Demir

Department of Electrical and Electronics Engineering, Bilkent University, 06800 Ankara, Turkey

1. Introduction

This lab is designed to determine the DC motor's transfer function using Fourier analysis. Sinusoidal signals are applied to the motor, and its response is recorded, enabling the extraction of both magnitude and phase characteristics across various frequencies for comparison.

2. Laboratory Content

Part 1

In the first part of the preliminary, we are ask to use the first order transfer function we derived in the first lab [1] (Eq.2) and create a bode plot a transfer function of our DC motor in a form of first order transfer function via the matlab code we are provided in the lab manual.

$$G(s) = \frac{K}{\tau s + 1} \quad (Eq. 1)$$

$$G(s) = \frac{13.791}{0.088s + 1} \quad (Eq. 2)$$

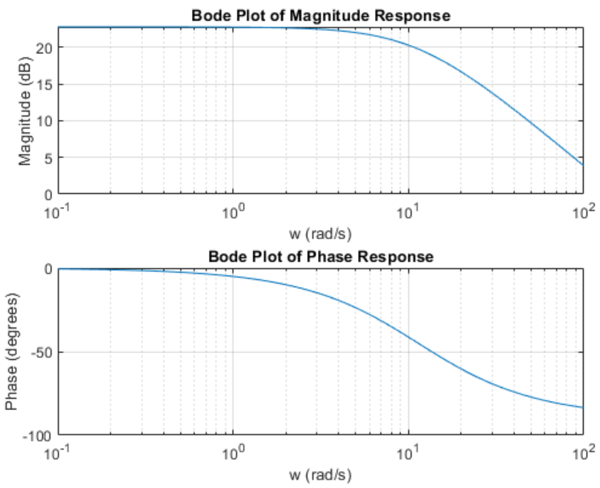

Fig. 1: Magnitude and Phase Response Plots of Eq.2

Part 2

In this part sinusoidal inputs were given to the DC motor and then magnitude and phase response pairs for angular frequencies: ω = 0.1, 0.2, 0.3, 0.6, 1, 2, 3, 6, 10, 20, 30, 60, 100 rad/s are derived and compared via plots.

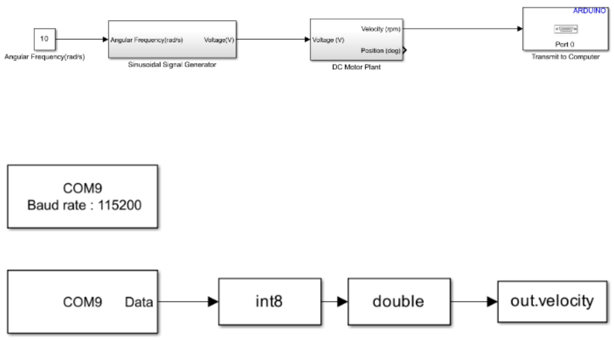

Fig. 1.2: Simulink Blocks of input of specified sinusoidal and an output

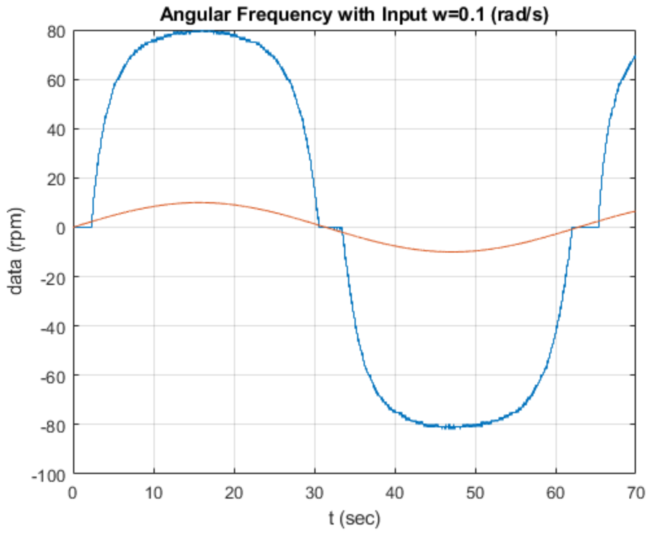

Fig. 2: Input-Output Signals when ω = 0.1 rad/s

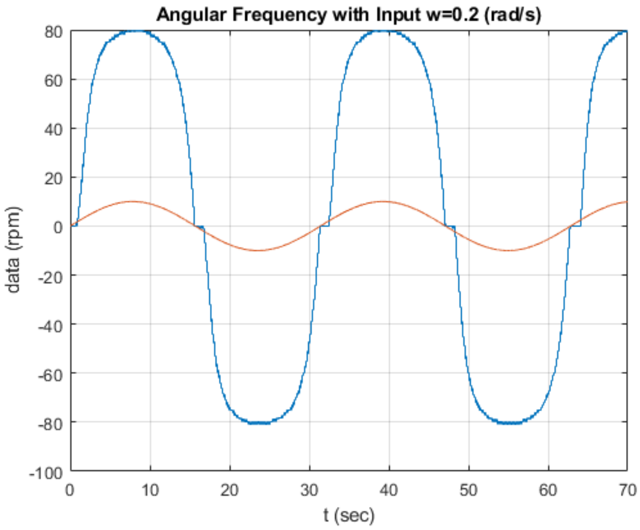

Fig. 3: Input-Output Signals when ω = 0.2 rad/s

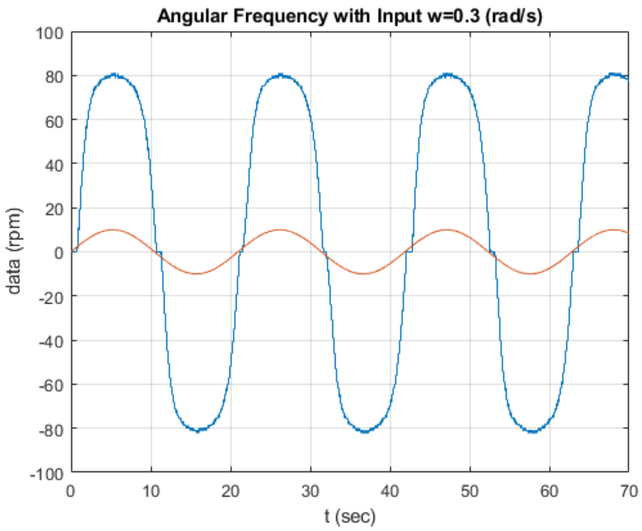

Fig. 4: Input-Output Signals when ω = 0.3 rad/s

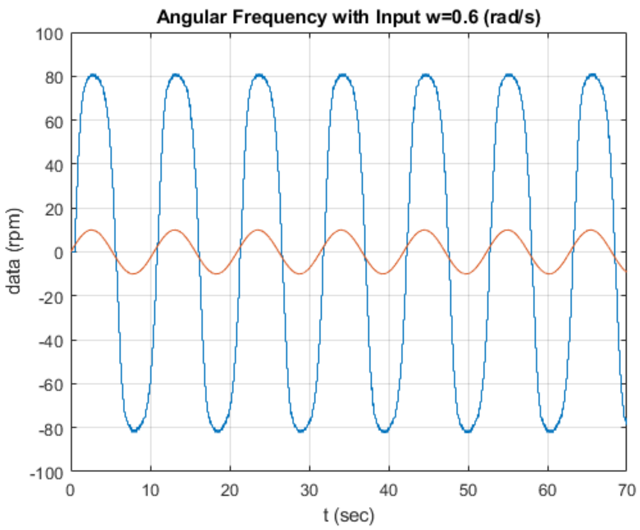

Fig. 5: Input-Output Signals when ω = 0.6 rad/s

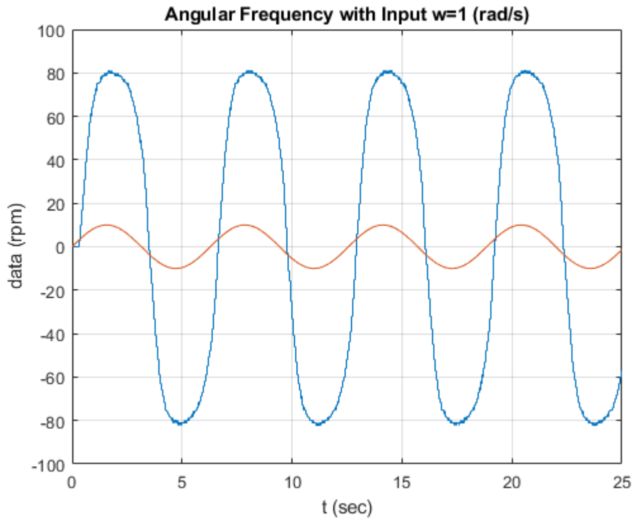

Fig. 6: Input-Output Signals when ω = 1 rad/s

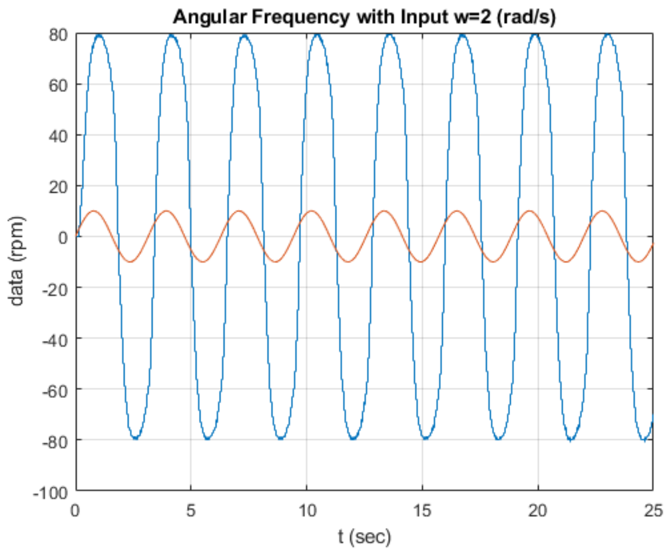

Fig. 7: Input-Output Signals when ω = 2 rad/s

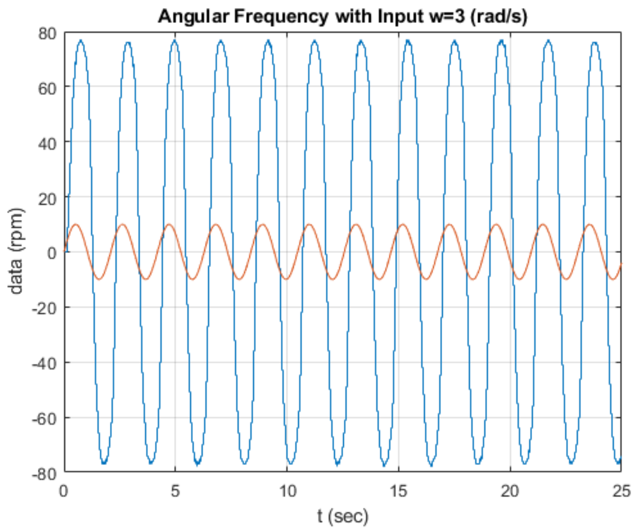

Fig. 8: Input-Output Signals when ω = 3 rad/s

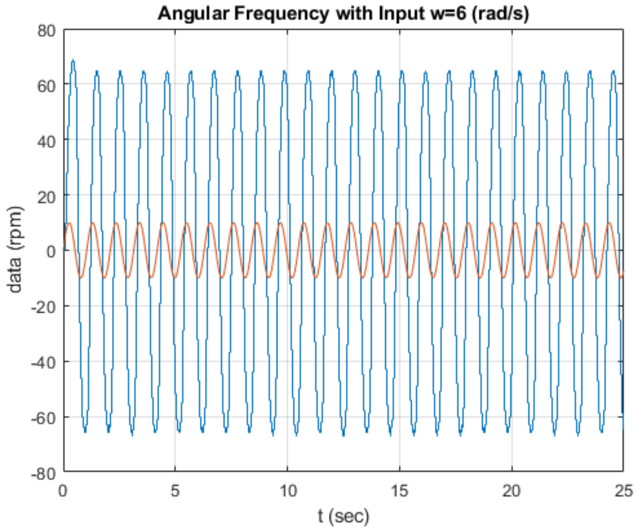

Fig. 9: Input-Output Signals when ω = 6 rad/s

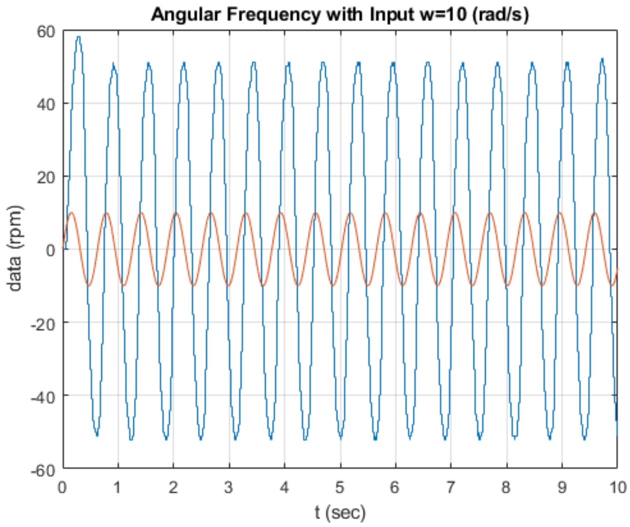

Fig. 10: Input-Output Signals when ω = 10 rad/s

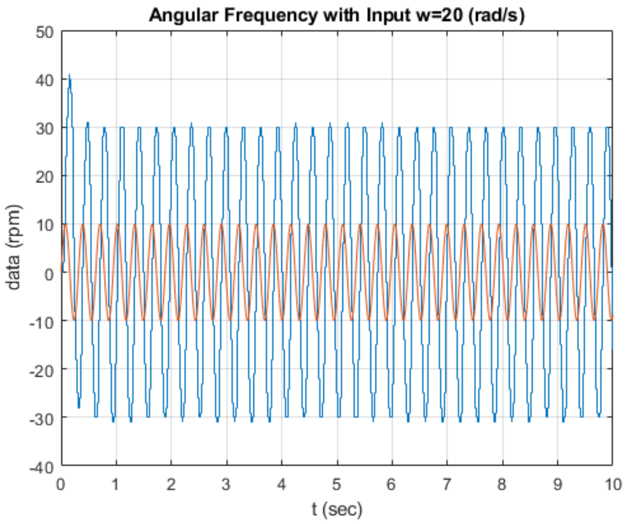

Fig. 11: Input-Output Signals when ω = 20 rad/s

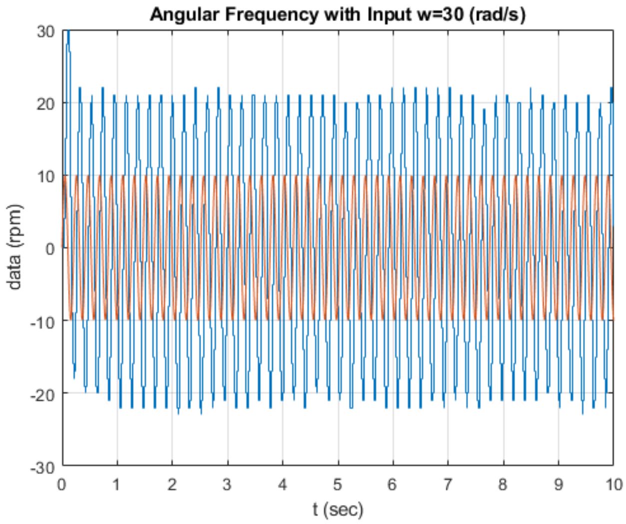

Fig. 12: Input-Output Signals when ω = 30 rad/s

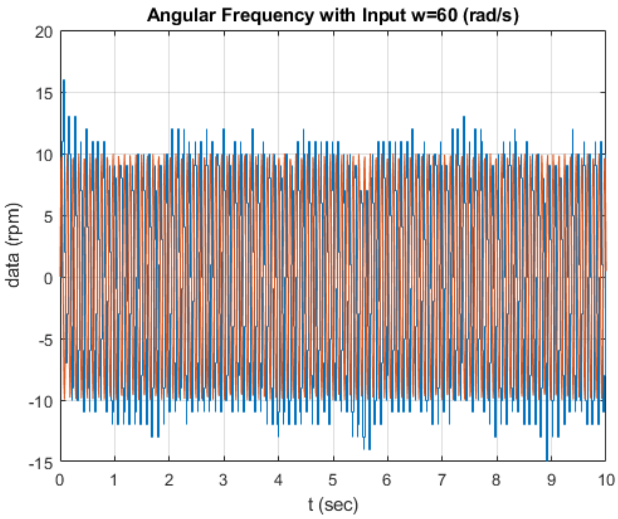

Fig. 13: Input-Output Signals when ω = 60 rad/s

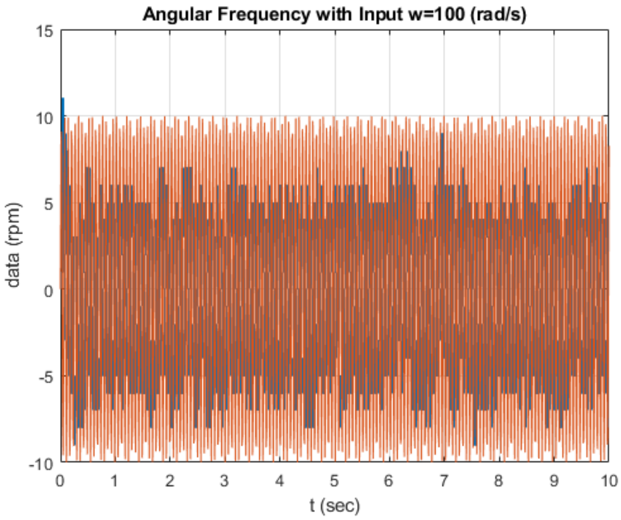

Fig. 14: Input-Output Signals when ω = 100 rad/s

A Bode plot was generated using 13 sample points by applying a sinusoidal input, x(t) = A sin(ωt) (Eq.3), and recording the corresponding output, y(t) = A|G(jω)| sin(ωt + ∠G(jω)) (Eq.4) since we have done in preliminary [2]. For each input-output measurement, we computed the 13-point FFT of both the input and output data arrays. By taking the differences in magnitude and phase between the FFT results, we derived the discrete 13-point transfer function, and then plotted the extracted magnitude and phase responses on the transfer function graph.

$$x(t) = A\sin(\omega t)\ (Eq.3)$$

$$y(t) = A|G(j\omega)|\sin\big(\omega t + \angle G(j\omega)\big)\ (Eq.4)$$

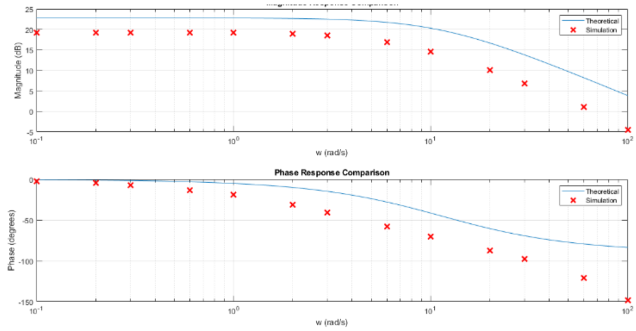

Fig. 15: Magnitude and Phase Response Compared with Experimental Results

The experimental data closely follows the ideal curve, with deviations in the magnitude response of less than 6 dB. However, the phase error increases with frequency, which can be attributed to the inherent time delay in the DC motor's processes.

Part 3

In this part, we will also consider the hardware system time delay of 10ms due to the processing requirements. At higher frequencies [3]. We are asked to make a first order Pade Approxiamtion for the 10ms delay. So we change our transfer function as follows:

$$G_{paded}(s) = \frac{13.791}{0.088s + 1} * \frac{1 - 0.005s}{1 + 0.005s}\ (Eq.5)$$

We are expected a phase change however, a phase change won’t affect the magnitude. Because we are given a new transfer function to only adjust the phase difference.

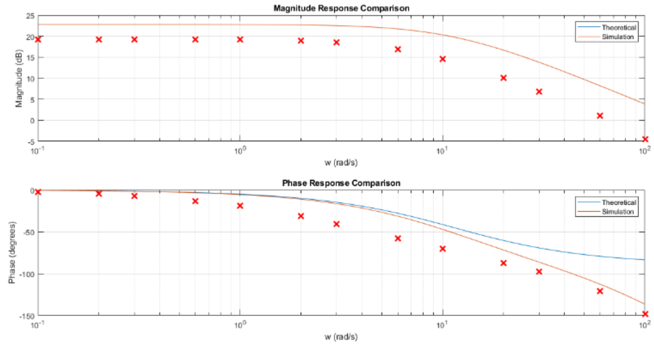

Fig. 12: Pade Approximation Results on Both Magnitude and Phase Plot

3. Conclusion

In the first part of the assignment, the magnitude and phase responses of the transfer function were directly computed and plotted. In the second part, we derived the magnitude and phase responses by analyzing the input-output relationship using 10 data points. After generating the time-domain input-output signals, the FFT (Fast Fourier Transform) was applied to obtain the corresponding frequency-domain responses. The results obtained from both the analytical and FFT-based approaches were consistent with each other, validating the accuracy of the analysis.

REFERENCES

1. EE342 Spring 2025, Lab work 1- Ezgi Demir
2. EE342 Spring 2025, Preliminary Work 2- Ezgi Demir
3. R. H. Bishop and R. C. Dorf, Modern Control Systems: International Edition, 10th ed. Upper Saddle River, NJ: Pearson, 2005.