EEE3094S LAB 1

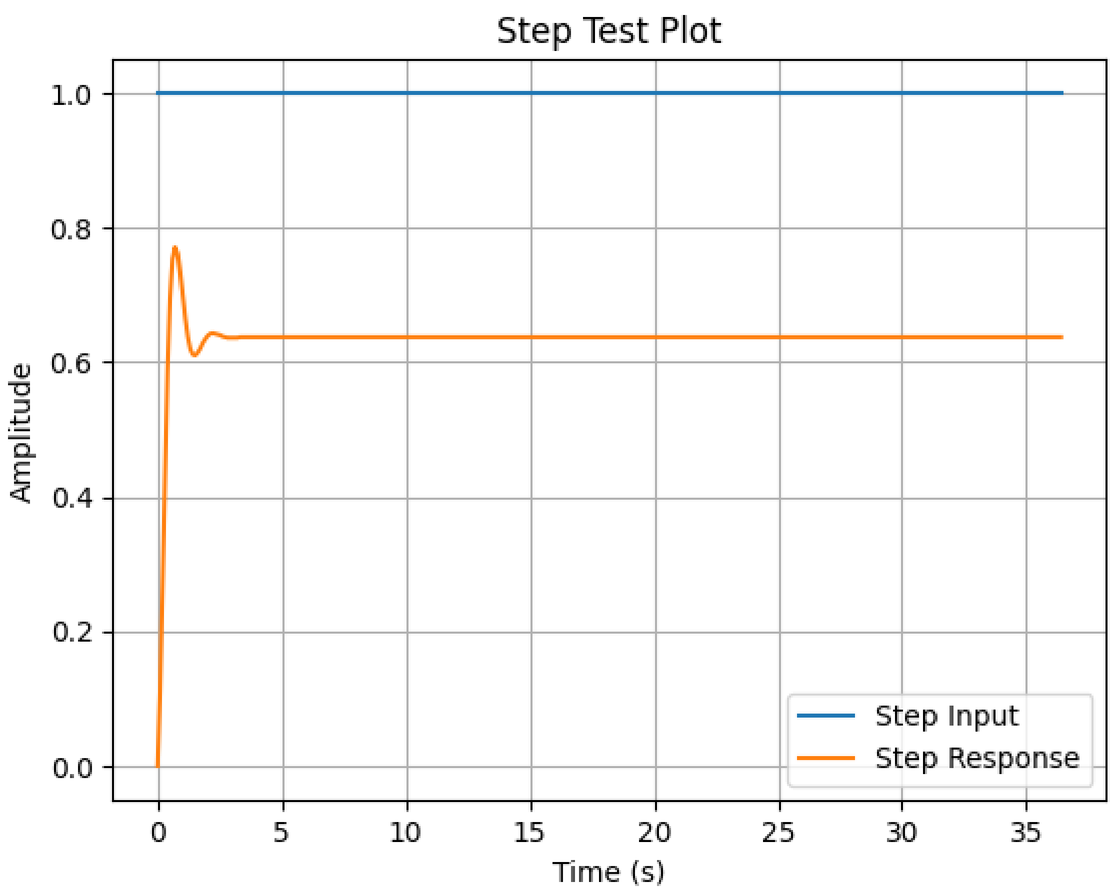
Name: Travimadox Webb

Student Number: WBBTRA001

1.Step Test

1.1 Data Collection

A step input of magnitude '1' was applied to the system and data was recorded and plotted as shown below:



1.2 Step Data Analysis

Methodology to Obtain System Parameters using Step Response

A step response is a common approach to characterizing the behavior of a system. By analyzing the step response of a system, we can derive key parameters which define its behavior. Below, we outline the steps and the corresponding equations used to obtain the system parameters from the step response:

i. System Gain

The system gain (also known as steady-state gain) is defined as the value of the system's response as time approaches infinity. It's the value that the system's output settles to after a long time following a step input.

$$\text{Gain} = \text{output\_displacement}[-1]$$

ii. Peak Time and Peak Value

The peak time (t_p) is the time at which the step response reaches its maximum (peak) value.

$$t_p = \text{time}[\text{idx}]$$

$$\text{Peak Value} = \max(\text{output\_displacement})$$

iii. Percent Overshoot

The percent overshoot ($\%\text{OS}$) is a measure of how much the system's response overshoots its final steady-state value.

$$\%\text{OS} = \frac{\text{Peak Value} - \text{Gain}}{\text{Gain}} \times 100$$

iv. Damping Ratio and Natural Frequency

The damping ratio (ζ) and the natural frequency (ω_n) are critical parameters in defining the behavior of a second-order system. They can be derived from the percent overshoot and peak time:

$$\zeta = \frac{-\ln(\%\text{OS}/100)}{\sqrt{\pi^2 + \ln^2(\%\text{OS}/100)}}$$

$$\omega_n = \frac{\pi}{t_p \times \sqrt{1-\zeta^2}}$$

v. Transfer Function

Using the system gain, damping ratio, and natural frequency, the transfer function of the system can be formulated. For a standard second-order system, the transfer function is given by:

$$G(s) = \frac{\text{Gain} \times \omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

From the above it can be infered that:

$$Gain \approx 0.637$$

$$\zeta \approx 0.4445$$

$$\omega_n \approx 5.01 rad/s$$

Given the damping ratio and natural frequency, the poles of the system can be determined using the quadratic equation:

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$$

The poles of the system are at:

$$s_1, s_2 = -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2 - 1}$$

$$s_1 = -2.227 + j4.487$$

$$s_2 = -2.227 - j4.487$$

The transfer function of the system from the above is then:

$$G(s) = \frac{\text{Gain} \times \omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$G(s) = \frac{0.637 \times 5.01^2}{s^2 + 2 \times 0.4445 \times 5.01 s + 5.01^2}$$

2.Frequency Response Test

2.1 Data Collection

Different sinusoidal inputs with an amplitude of 1 were applied to the system. To assess the system's response, we calculated both the gain and phase. Here's how they were determined:

Gain:

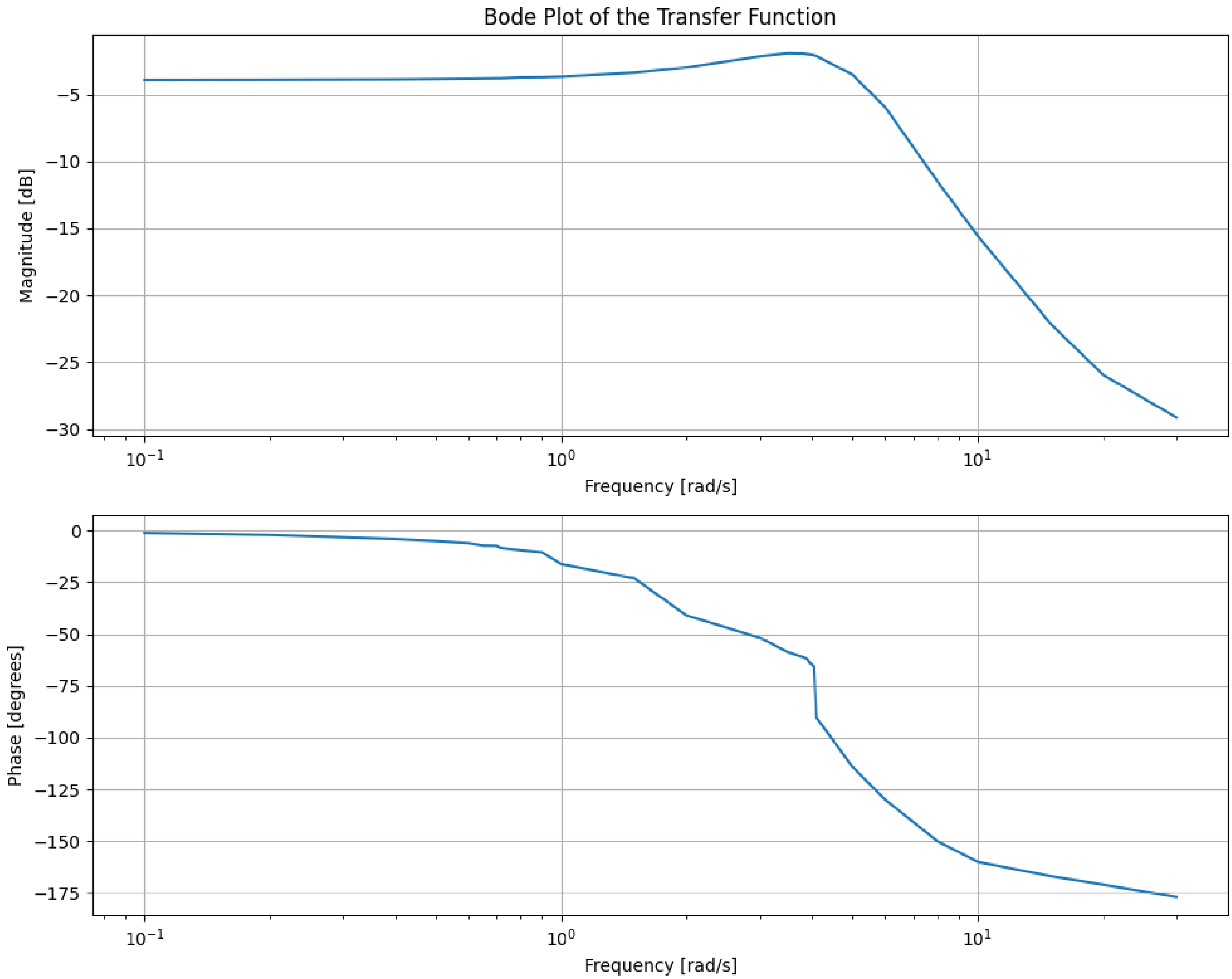
$$\text{Gain (dB)} = 20\log\left(\frac{\text{Output Amplitude}}{\text{Input Amplitude}}\right)$$

Phase:

$$\Delta\phi = \left(\frac{\Delta t}{T}\right) \times 360^\circ$$

Where **T** is the period of the sinusoid

The gain and phase data was then used to plot bode plot as shown below:



3. System Model

Damping coefficient:

$$b = 2\zeta\omega_n = 2 \times 0.4445 \times 5.01 = 4.454$$

Spring coeffcient:

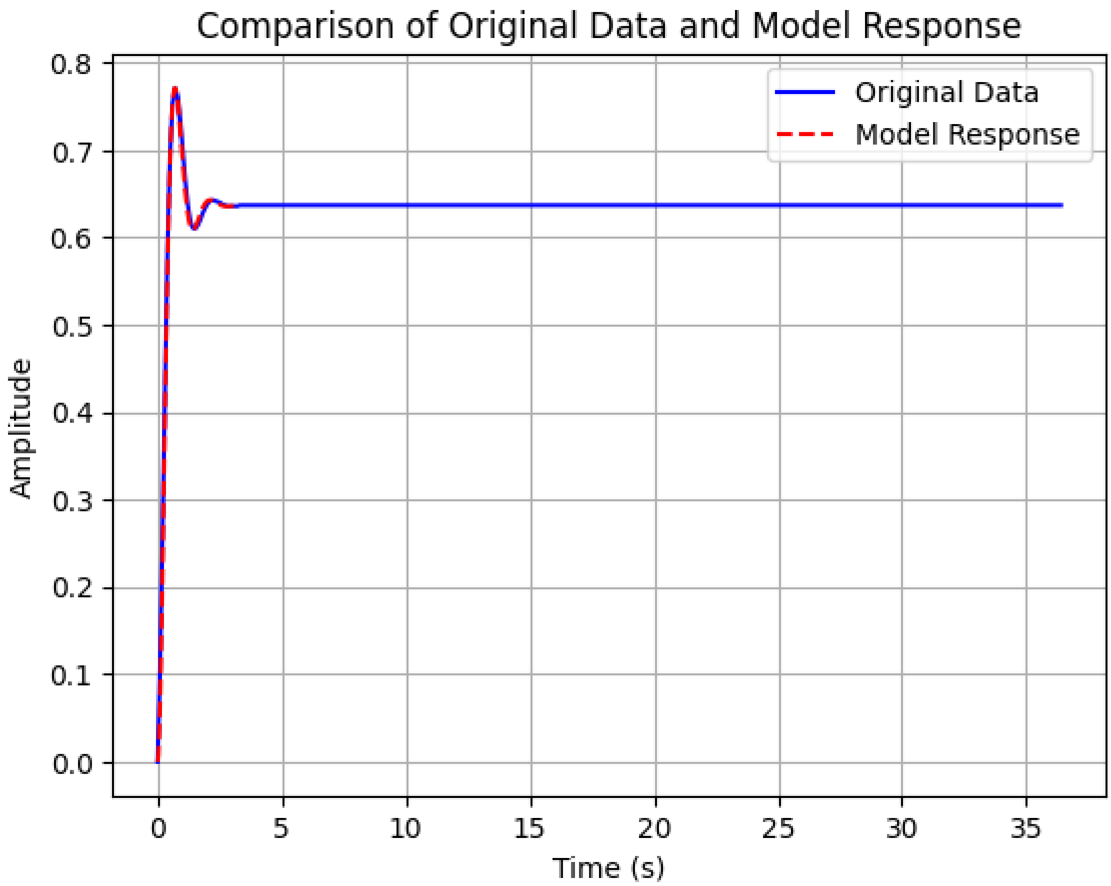
$$k = \omega_n^2 = 5.01^2 = 25.10$$

Transfer Function:

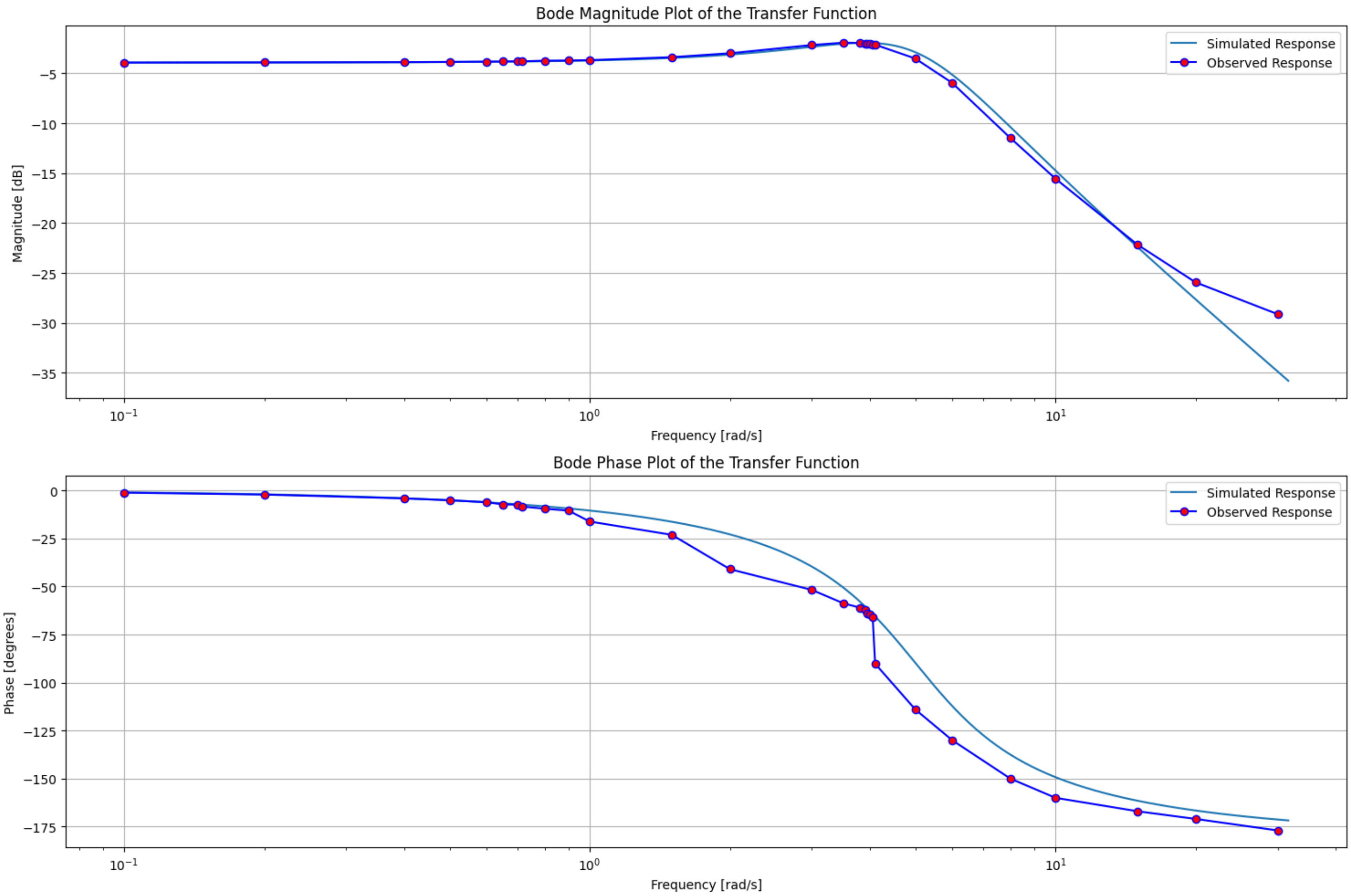
$$G(s) = \frac{0.637 \times 5.01^2}{s^2 + 2 \times 0.4445 \times 5.01s + 5.01^2}$$

4.Validation

4.1 Simulated vs. observed step response



4.2 : Simulated vs. observed frequency response



4.3: Validation Analysis

Step Response

- The step response from our experiment matched perfectly with our predictions. This means our model seems accurate based on this test.

Bode Magnitude Plot

- For lower frequencies (left of a certain point we call the system's "natural frequency"), our predicted and actual measurements were almost the same.
- For higher frequencies (right of the natural frequency), our predictions were a bit off compared to our actual measurements, especially at the very high frequencies.

Bode Phase Plot

- Again, for lower frequencies, our predictions and measurements matched really well.
- For higher frequencies, there were some small differences. Our actual measurements showed slightly different phase values than our predictions, but the general shape was the same.

In short, our model works really well for lower frequencies, but there are some differences at higher frequencies that we might need to look into.

Appendix

The jupyter notebook used to analyse the experiment data can be found at:Lab Data