EE 3CL4

Lab 2

-

Stefan Tosti - Tostis - 400367761 - L06 - C02
Connor Usaty - Usatyc - 400409624 - L06 - C01

2024 - 02 - 19

Section 1 - Contributions

Both group members were responsible for an even amount of contribution to this lab experiment. Pre-lab calculations were done as a group, before the designated lab time. In the lab, the experiments were carried out as a group with each member responsible for contributing to the required Simulink model and acquiring data. Once completed, the report was written by both group members contributing ideas to each section simultaneously.

Section 2 - Objectives

The objective of this lab was to identify the plant (process) model of a marginally-stable DC servomotor. This was done by performing closed-loop analysis in both the time and frequency domain on the laboratory motor system in order to obtain the transfer function and associated parameters - A and τ_m.

Section 3 - Time Domain Approach

The time domain approach of this lab included our group setting the motor up such that we could see an entire period of the system's step response (6 seconds). Once this was completed, Simulink was used to produce the graph found below. Using the measurement environments cursor functionality, our group was able to measure the peak value of the step response $\left(M_{pt}\right)$ as well as the final value $\left(f_v\right)$ of the system's step response, which were found to be *1.598 seconds* and *1.015 radians* respectively. Refer to *Figure 2* in the Appendix. With this information, as well as Equation 2 in the pre-lab hints document, our group was able to calculate Percent Overshoot of the system. The calculation can be found in *Figure 3* of the appendix, we obtained a result for Percent Overshoot of *57.438%.* Once completed, our group measured the time at which M_{pt} occurred, and we obtained T_p *= 0.088 seconds.* With all of this measured information, we were finally able to compute the values of ξ and ω_n. Find below in *Figure 4* of the appendix for detailed calculations. We obtained results of 0.173805 and 36.2517 $\frac{rad}{s}$ for ξ and ω_n respectively. Finally, we were able to compute the values of A and τ_m to help us define our system. Detailed calculations can be found in *Figure 5* of the appendix. We obtained values of 0.079356 and 26.0721 for τ_m and A respectively. Our group also exported this data from Simulink into Excel, in order to generate a plot of the motors step response in the time domain. Refer to *Figure 6* in the appendix.

Section 4 - Frequency Domain Approach

Our group began experiment 2 by experimentally measuring the values of M_p and ω_p for specified values of input frequency. The plots for each input frequency can be found below in the appendix, *Figures 7 - 13*. At each of these input frequencies, our group noted down the amplitude of the output waveform. All of these amplitudes can be found in *Figure 14* of the appendix. We used this to identify that, of the coarse-grain search, the largest amplitude occurred at $2\pi * 5$ input frequency, with an amplitude of 3.533. We then conducted a fine-grain search around this center frequency, and recorded input frequency values from $2\pi * 4.5 - 2\pi * 5.5$ with a step of 0.1 on the multiplier of 2π. The results from our fine grain search can be found in *Figure 15* of the appendix. The results of the fine-grain search told us that the maximum amplitude occurs at an input frequency of $2\pi * 5$ and has an amplitude of 3.588. Knowing that value of ω_p and M_p for our system, we were able to compute ω_n and ξ. These calculations can be found in *Figure 16* of the appendix. We obtained results of 32.0575 and 0.140755 for ω_n and ξ respectively. Finally, we were able to compute the values of A and τ_m to define our system. The calculations for this step can be found in *Figure 17.* Our group was also able to plot this Simulink data on Excel, for the case of $2\pi * 5$ input frequency. The plot can be found in *Figure 18* of the appendix below.

Appendix

Figure 1 - Time domain step response

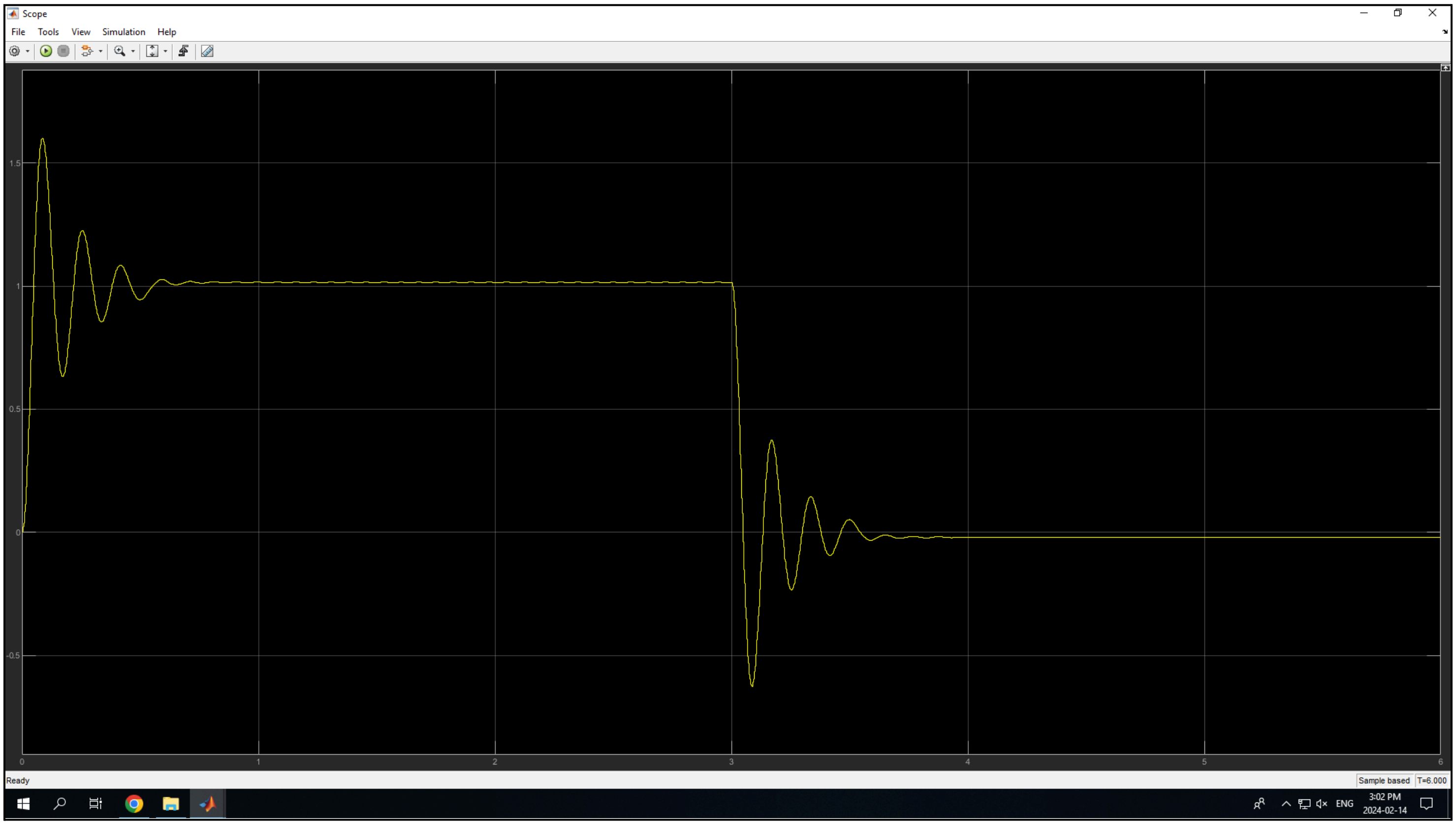

Figure 2 - Measurement of M_{pt} & f_v

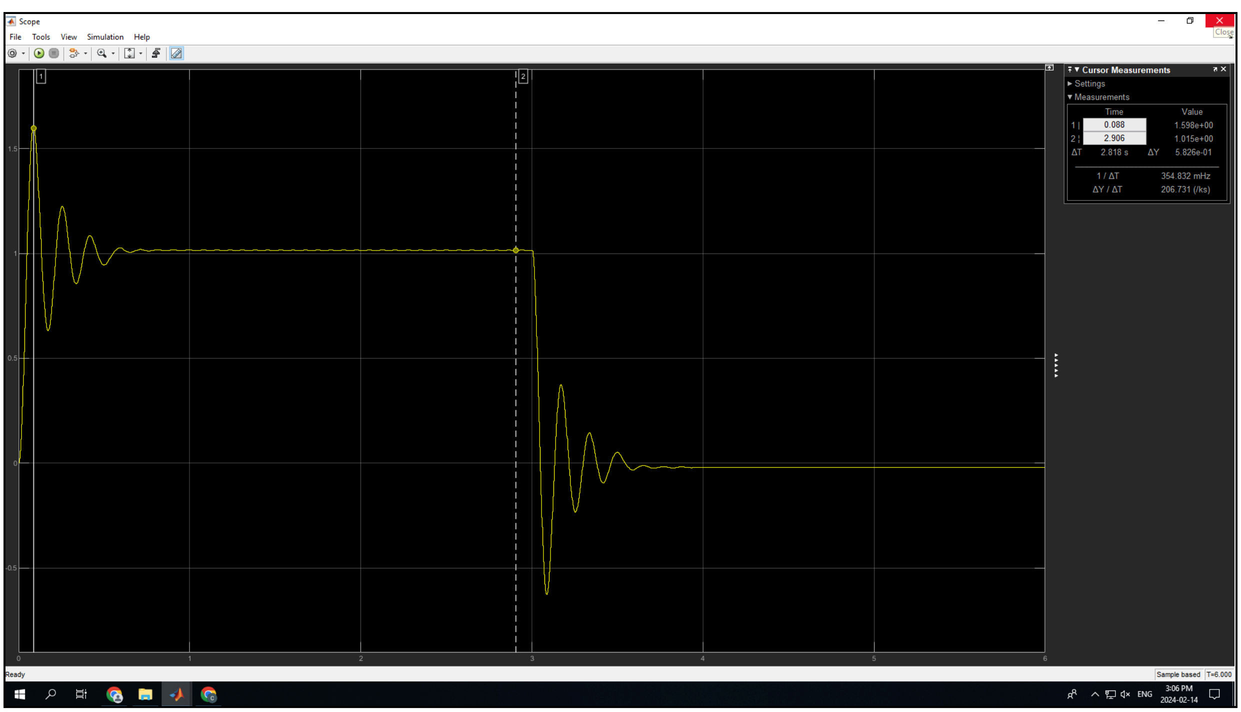

Figure 3 - Percent Overshoot Calculation

Experiment #1

$MPT = 1.598$

$fV = 1.015$

$$P.O = \frac{1.598 - 1.015}{1.015} \times 100\% = 57.438\%$$

Figure 4 - ξ & ω_n Calculation

$$\xi = \frac{\left| \ln\left(\frac{P.O}{100}\right) \right|}{\sqrt{\pi^2 + \ln^2\left(\frac{P.O}{100}\right)}} = 0.173805$$

$P.O = 57.438$

$$\omega_n = \frac{\pi}{T_p \sqrt{1 - \xi^2}} = 36.2517 \ \frac{rad}{s}$$

$T_p = 0.088$

Figure 5 - A & τ_m Calculation

$$\tau_m = \frac{1}{2\omega_n \zeta} = 0.079356$$

$\zeta =$
0.173805
$\omega_n =$
36.2517

$$A = \frac{\left(\frac{\omega_n}{2\zeta}\right)}{k} = 26.0721$$

$\zeta =$
0.173805
$\omega_n =$
36.2517
$k =$
4

Figure 6 - Time Domain Excel Plot

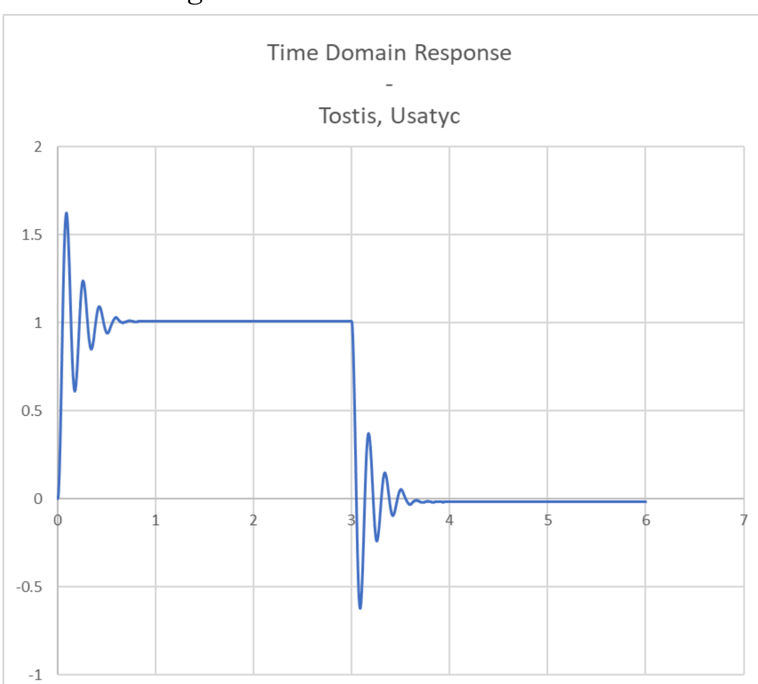

*Figure 7 - 2π * 1 input frequency*

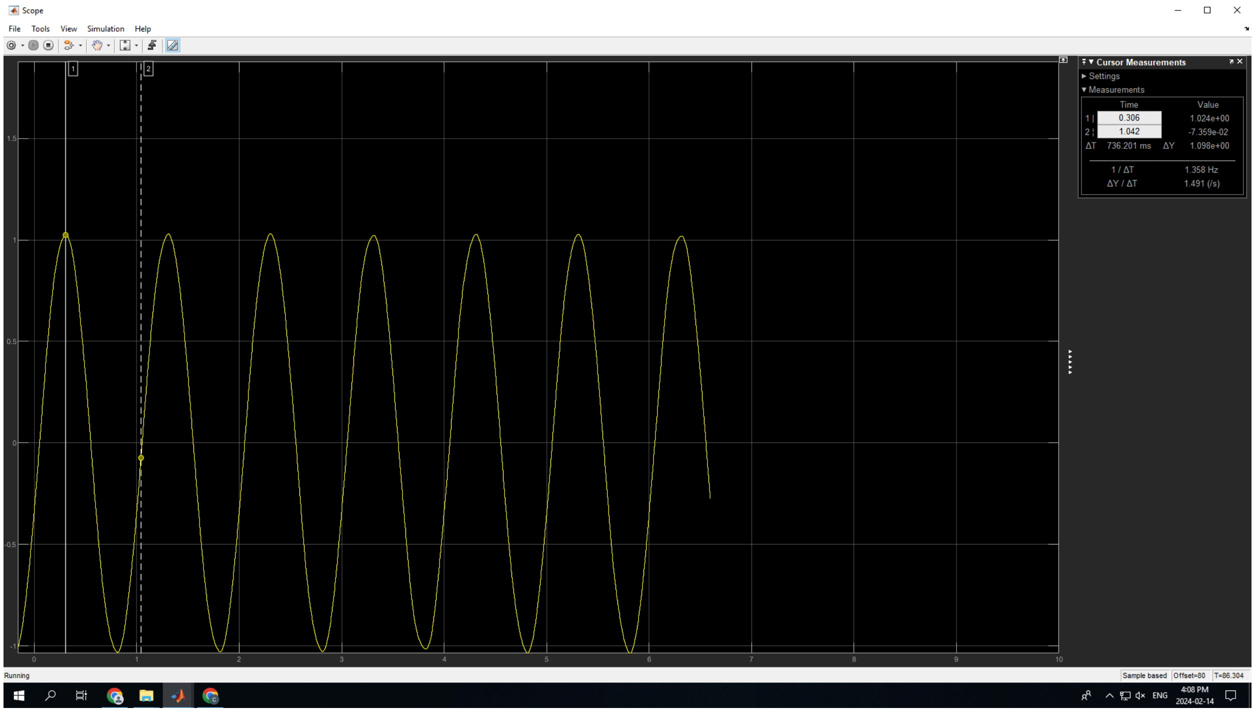

*Figure 8 - 2π * 2 input frequency*

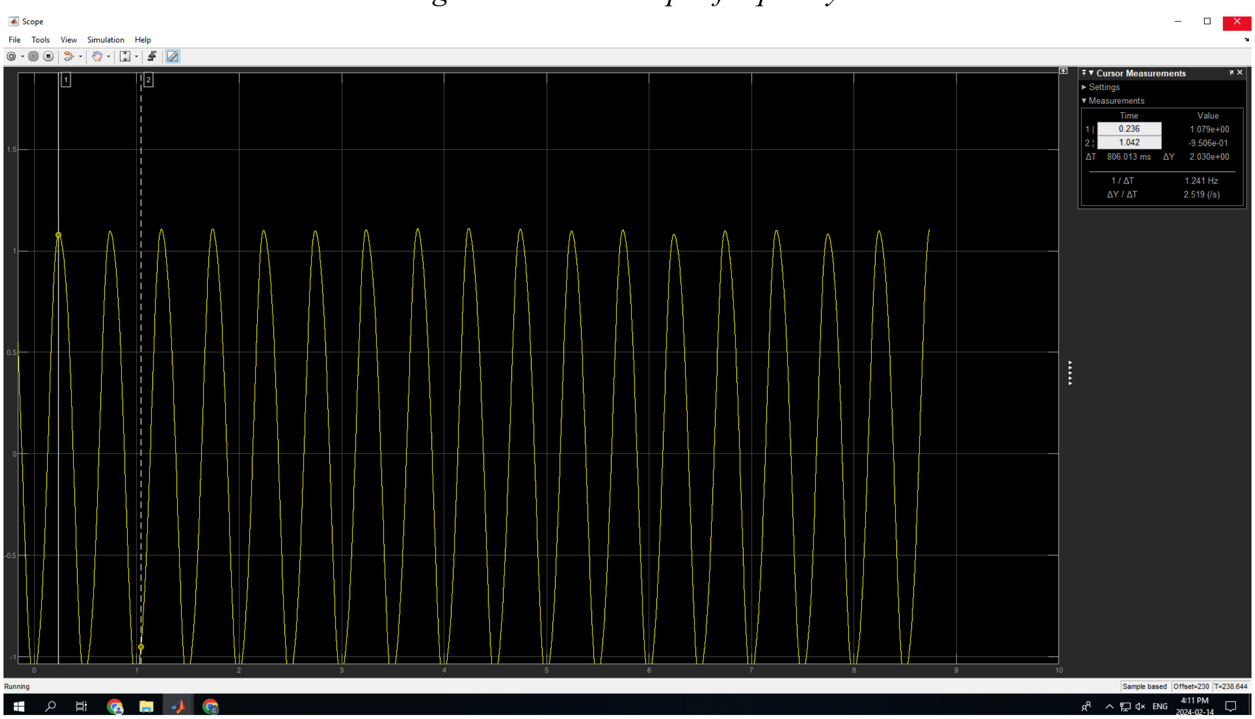

*Figure 9 - 2π * 3 input frequency*

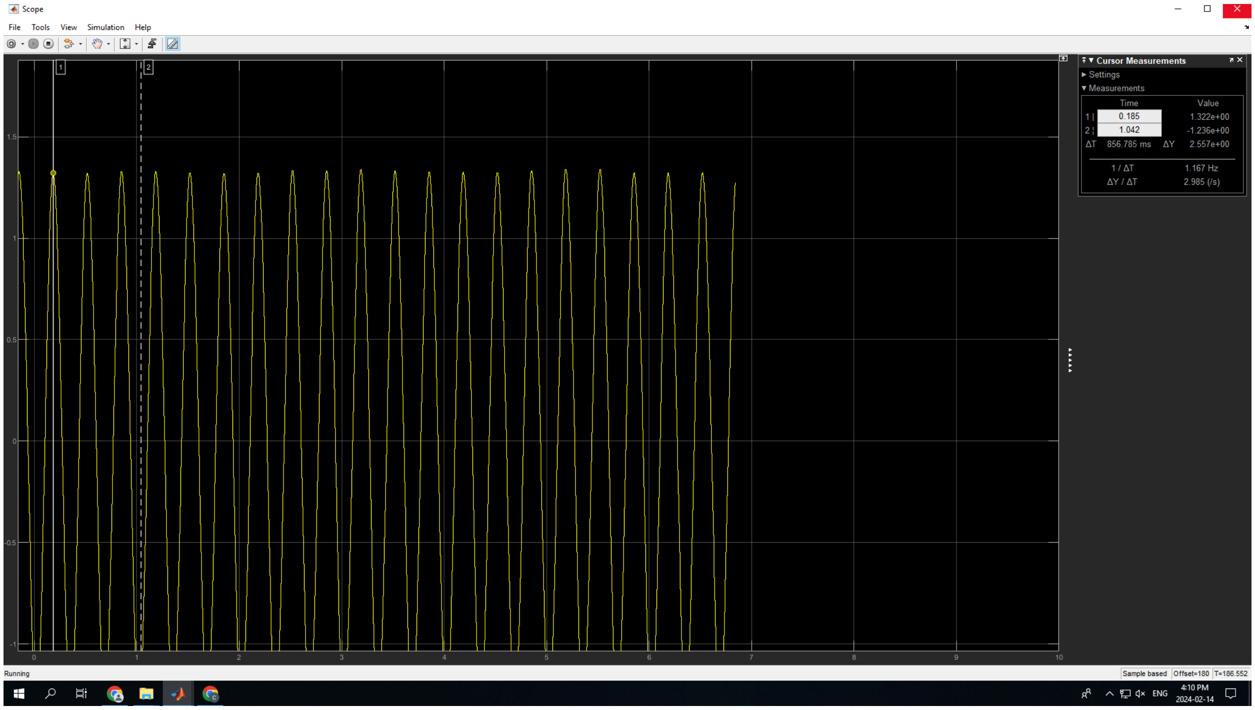

*Figure 10 - 2π * 4 input frequency*

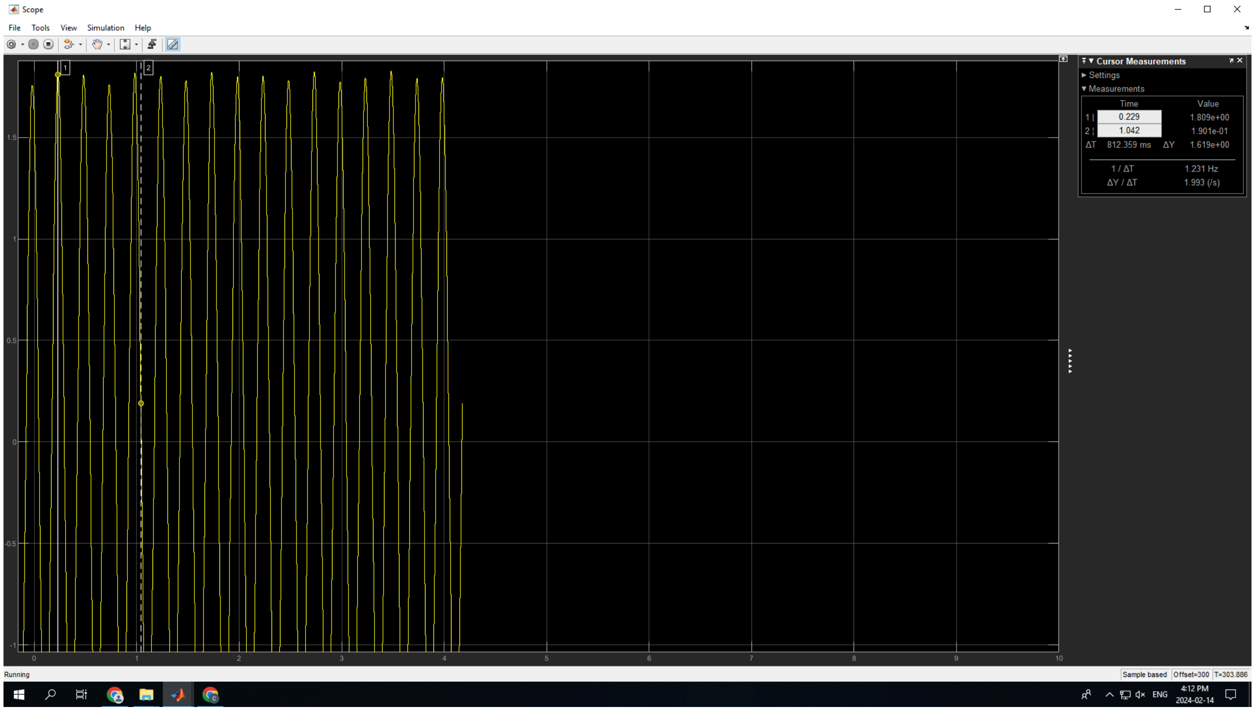

*Figure 11 - 2π * 5 input frequency*

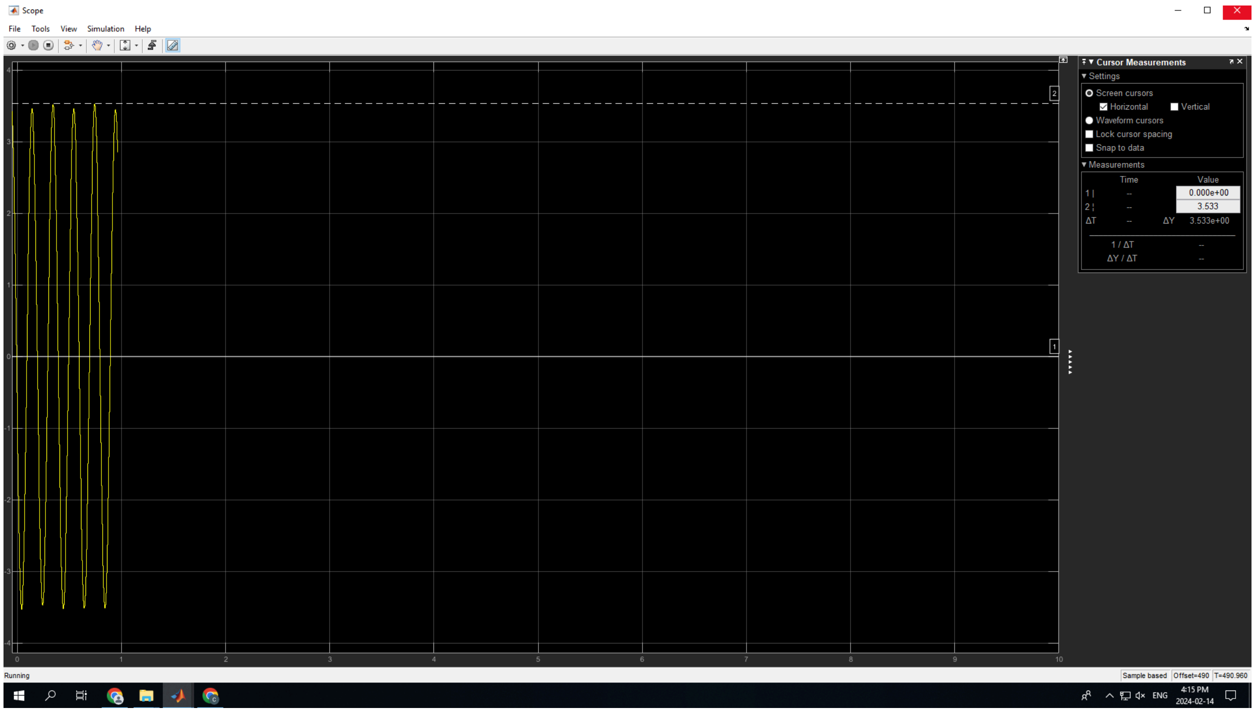

*Figure 12 - 2π * 6 input frequency*

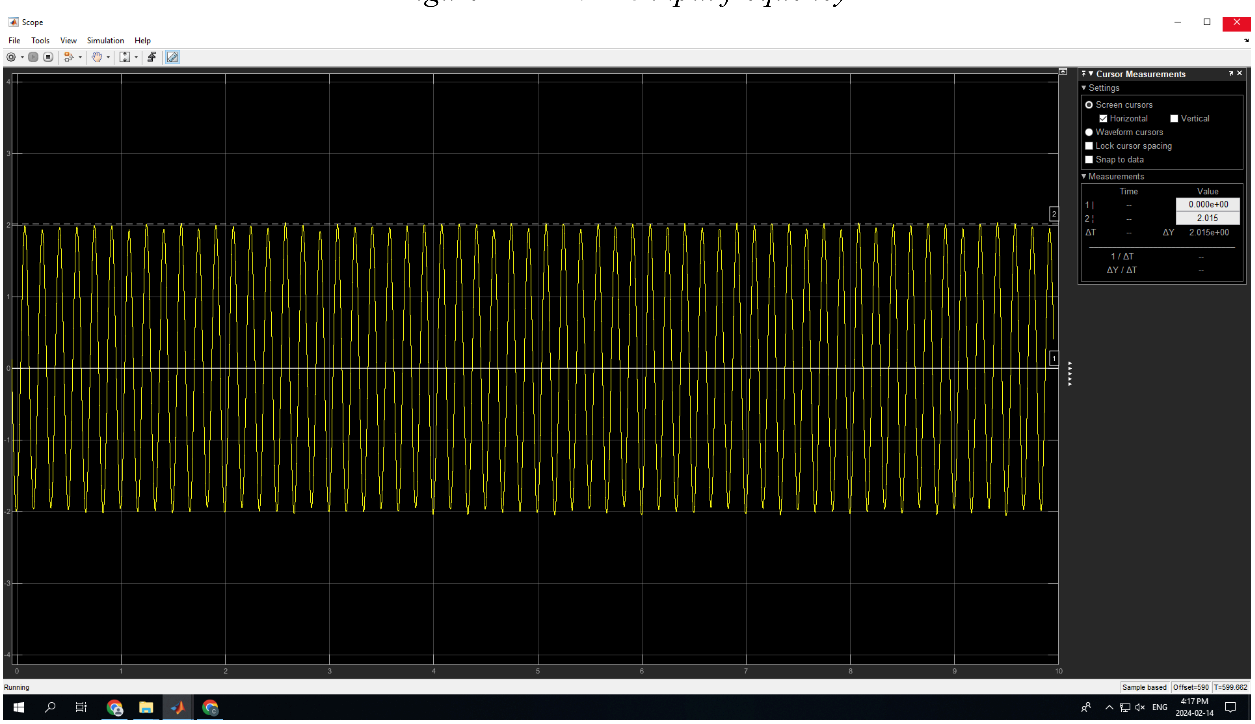

*Figure 13 - 2π * 7 input frequency*

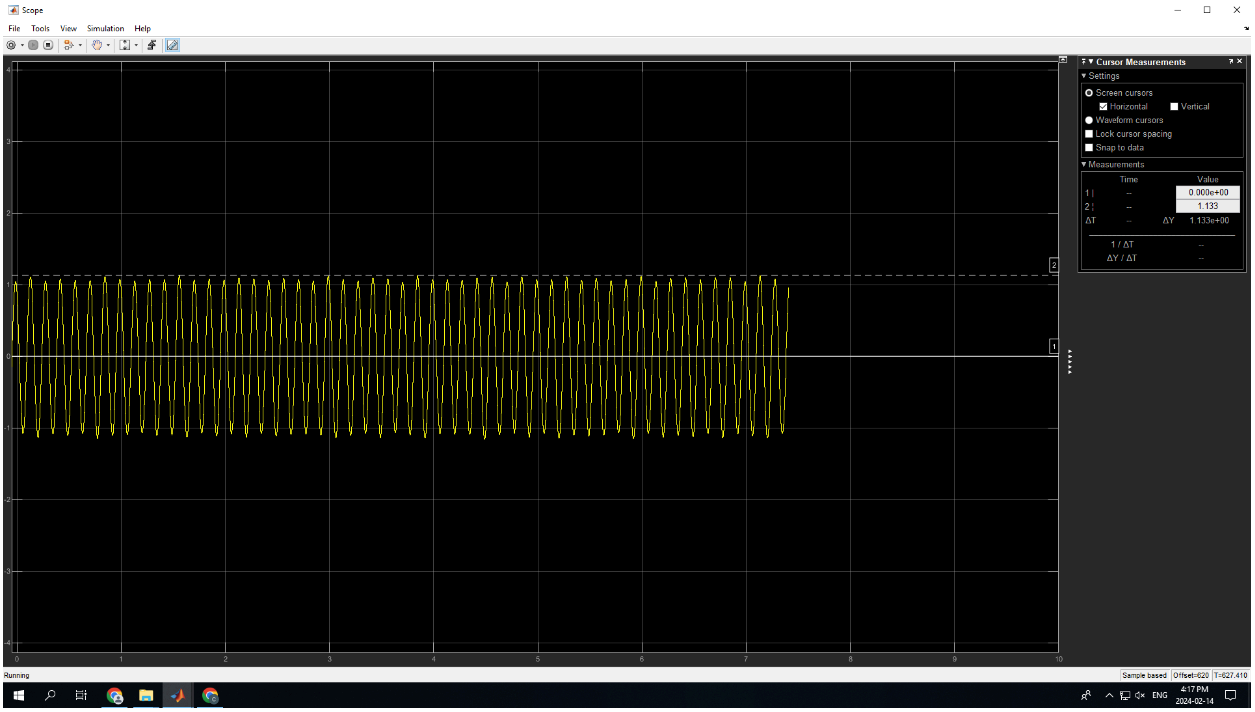

Figure 14 - Coarse-grain search amplitude results

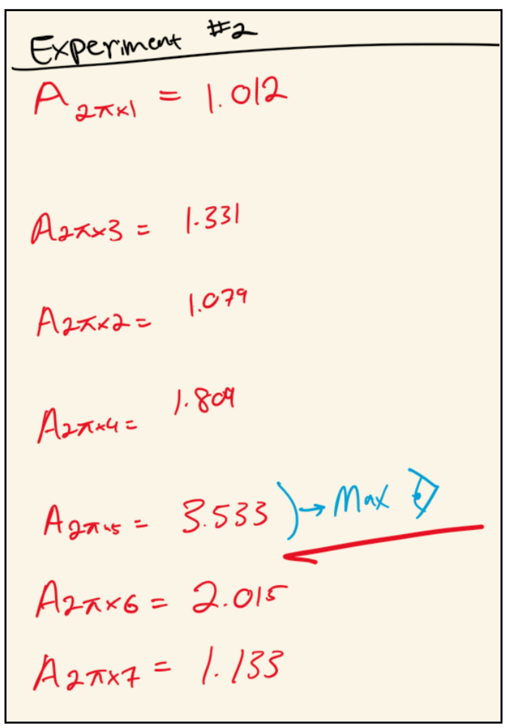

Figure 15 - Fine-grain search amplitude results

$$A_{2\pi\times 4.5} = 2.551$$

$$A_{2\pi\times 4.6} = 2.751$$

$$A_{2\pi\times 4.7} = 2.942$$

$$A_{2\pi\times 4.8} = 3.170$$

$$A_{2\pi\times 4.9} = 3.352$$

$$\left.A_{2\pi\times 5} = 3.588\right\}\text{max} \quad \theta = \omega_p = 5.0\times 2\pi$$

$$M_p = \frac{3.588}{1} = 3.588$$

$$A_{2\pi\times 5.1} = 3.473$$

$$A_{2\pi\times 5.2} = 3.452$$

$$A_{2\pi\times 5.3} = 3.252$$

$$A_{2\pi\times 5.4} = 2.988$$

$$A_{2\pi\times 5.5} = 2.806$$

Figure 16 - ω_n & ξ calculations

$$\omega_n = \frac{\omega_p}{\sqrt{1 - 2\left(\frac{-4mp^2 \pm \sqrt{16mp^4 - 16mp^2}}{-8mp^2}\right)^2}} = 32.0575$$

$\omega_p = 5 \times 2\pi$

$mp = 3.588$

$$\xi = \sqrt{\frac{-4mp^2 \pm \sqrt{16mp^4 - 16mp^2}}{-8mp^2}} = 0.99$$

Not Reasonable for underdamped

$$= 0.140755$$

$mp = 3.588$

Figure 17 - A & τ_m Calculations

$$A = \frac{\left(\frac{\omega_n}{2\xi}\right)}{k} = 28$$

$\omega_n = 32.0575$

$\xi = 0.140755$

$$\tau_m = \frac{1}{2\xi\omega_n} = 0.1108$$

$\xi = 0.140755$

$\omega_n = 32.0575$

Figure 18 - $2\pi * 5$ input frequency Excel plot