EE 352 – VELOCITY CONTROL SYSTEM

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EE352 AUTOMATIC CONTROL - EXPERIMENT 02

Department of Electrical & Electronic
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Title: Velocity Control System

Aim: The aim of this practical is studying the characteristics of a closed loop system using an experimental velocity control system

Objectives:

1. Understand the impact of the closed loop gain on the speed of operation and stability
2. Understand the impact of velocity feedback on a closed loop position control system
3. Understand the impact of the gain on the steady state and transient responses of a velocity feedback control system

Materials:

1. Analogue Unit (33-110) by Feedback Control & Instrumentation **(Setup 1)**
2. Mechanical Unit (33-100) by Feedback Control & Instrumentation **(Setup 1)**
3. Power Supply $\pm 15\ Vdc$, 1.5 A; $+5\ Vdc$, 0.5 A by Feedback Control & Instrumentation
4. Storage Oscilloscope

Procedure:

Follow the instructions extracted from the *"Servo Fundamentals Trainer"* in the following order:

1. Stability and the effect of loop gain: Assignment 5,
   a) Practical 5.1: Measuring transient response
   b) Practical 5.2: The effect of gain on stability
2. Velocity Feedback: Assignment 6,
   a) Practical 6.1: Simple Velocity Feedback
3. Following Error: Assignment 7,
   a) Practical 7.1: Following Error
   b) Practical 7.2: Velocity Feedback
4. Unstable System: Assignment 8,
   a) Practical 8.1: Adding a Longer Time Constant
   b) Practical 8.2: Instability at high gains

5. Closed Loop Speed Controls: Assignment 9,
    a) Practical 9.1: Closed loop Speed Control with Brake Loading

Observations:

Make the below mentioned observations while following the procedure above:

1. Stability and the effect of loop gain: Assignment 5,
    a. Practical 5.1: Step response
        i. Observe the transient response using a closed loop control system for a step input.
        ii. Calculate rise time, settle time, steady state gain & percentage overshoot using your observations.
        iii. Observe the effect of gain by setting the amplifier feedback resistor to $100\ k\Omega$ (gain=1).
        iv. Observe the effect of gain by setting the amplifier feedback resistor to $330\ k\Omega$ (gain=3.3).
        v. Observe the effect of gain by setting the amplifier feedback resistor to $1\ M\Omega$ (gain=10).
        vi. Compare your results.

2. Velocity Feedback: Assignment 6,
    a. Practical 6.1: Simple Velocity Feedback
        i. Compare the effect of the velocity feedback on transient response, when the gain is increased.
        ii. What happen when the polarity of the velocity feedback is reversed.

3. Following Error: Assignment 7,
    a. Practical 7.1: Following Error
        i. Describe how to observe the following error in X-Y mode in the oscilloscope.
        ii. Compare the results when,
            a) input & output resistance is $100\ k\Omega$.
            b) input $2 \times 100\ k\Omega$ in parallel & output is $100\ k\Omega$.
            c) input $100\ k\Omega$ & output is $500\ k\Omega$.
    b. Practical 7.2. Velocity Feedback
        i. What are the effects of velocity feedback on following error, compare the results with previous step (practical 7.1).

4. Unstable System: Assignment 8,
    a. Practical 8.1: Additional Time Constant
        i. Using the oscilloscope observe the time constant in X-Y mode as well as X-T, Y-T mode.
        ii. What happen to the time constant when 1 $M\Omega$ resistor replaced by,
            a) $330\ k\Omega$
            b) $100\ k\Omega$
    b. Practical 8.2: Unstable System
        i. Using the oscilloscope observe the time constant in X-Y mode as well as X-T, Y-T mode.
        ii. Observe the system stability at different gain settings by replacing feedback resistor with,
            a) $330\ k\Omega$
            b) $1\ M\Omega$

5. Closed Loop Speed Controls: Assignment 9,
    a. Practical 9.1: Closed-loop Speed Control
        i. Plot graphs for six brake settings with & without Velocity feedback for gain=1 and gain=10.

OBSERVATIONS

1. Stability and the effect of loop gain: Assignment 6,
   a. Practical 6.1: Step response
      i. Observe the transient response using a closed loop control system for a step input.

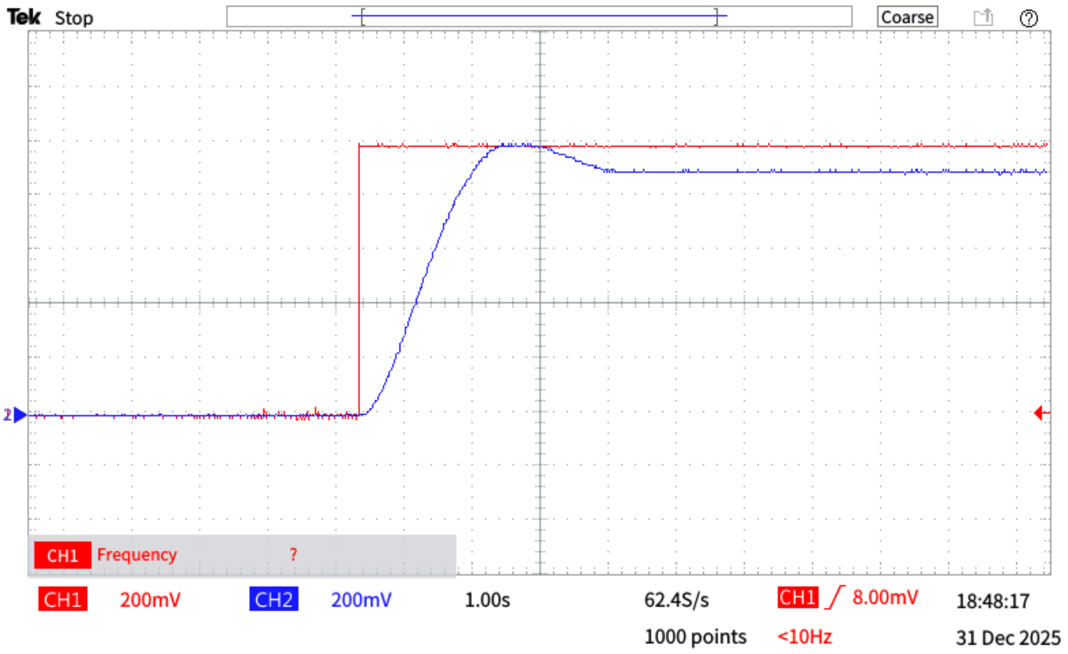

Figure 1 : Transient angular output response of a closed-loop control system for a step input.

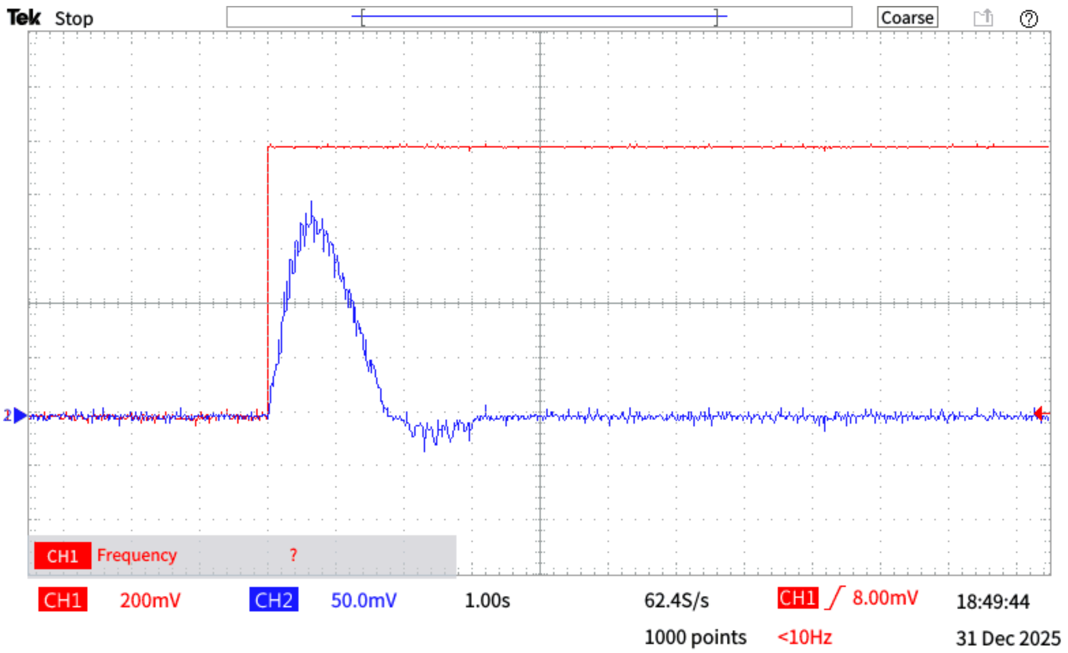

Figure 2 : Transient speed output response of a closed-loop control system for a step input.

ii. Calculate rise time, settle time, steady state gain & percentage overshoot using your observations.

Rise time: 1.0 s

Settle time: 3.0s

Steady state gain: 1.0

Percentage Overshoot: [(1.0 -0.9)) × 100 %] / (1.0) = 9 %

iii. Observe the the effect of gain by setting the amplifier feedback resistor to 100 Ω (gain=1).

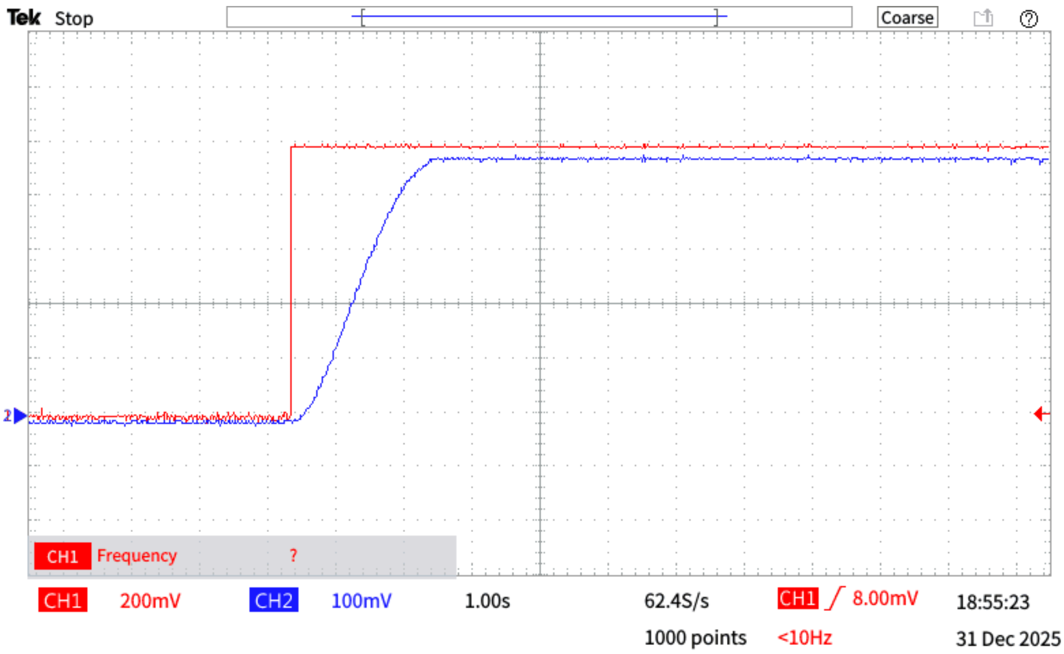

Figure 3 : Oscilloscope output showing the angular output response for an amplifier gain of 1 (feedback resistor = 100 kΩ)..

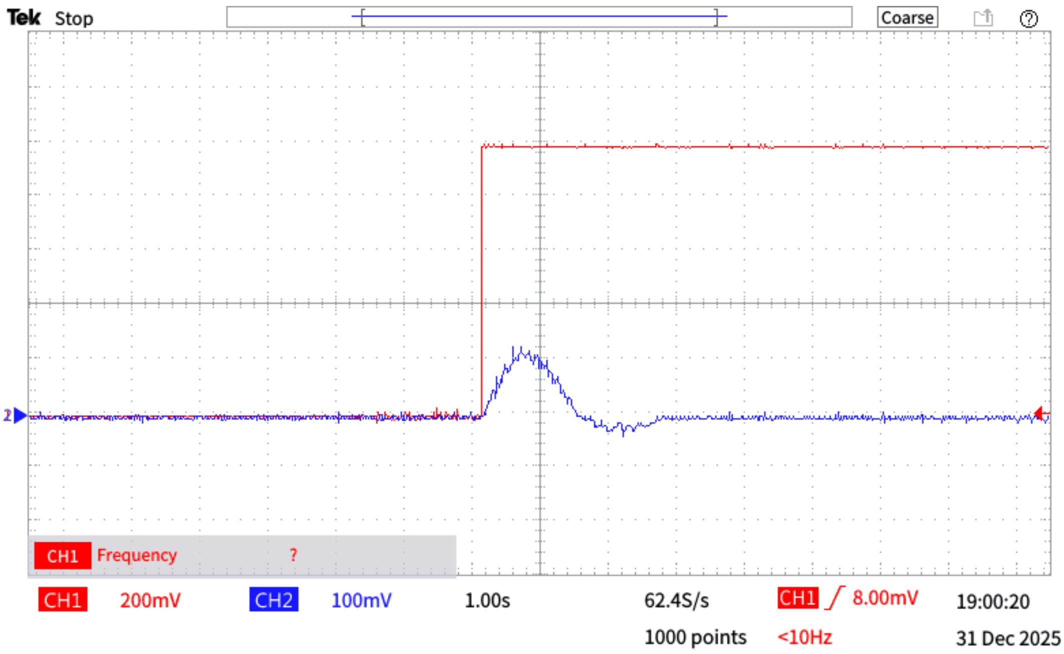

Figure 4 : Oscilloscope output showing the speed output response for an amplifier gain of 1 (feedback resistor = 100 kΩ)..

iv. Observe the the effect of gain by setting the amplifier feedback resistor to 330 Ω (gain = 3.3).

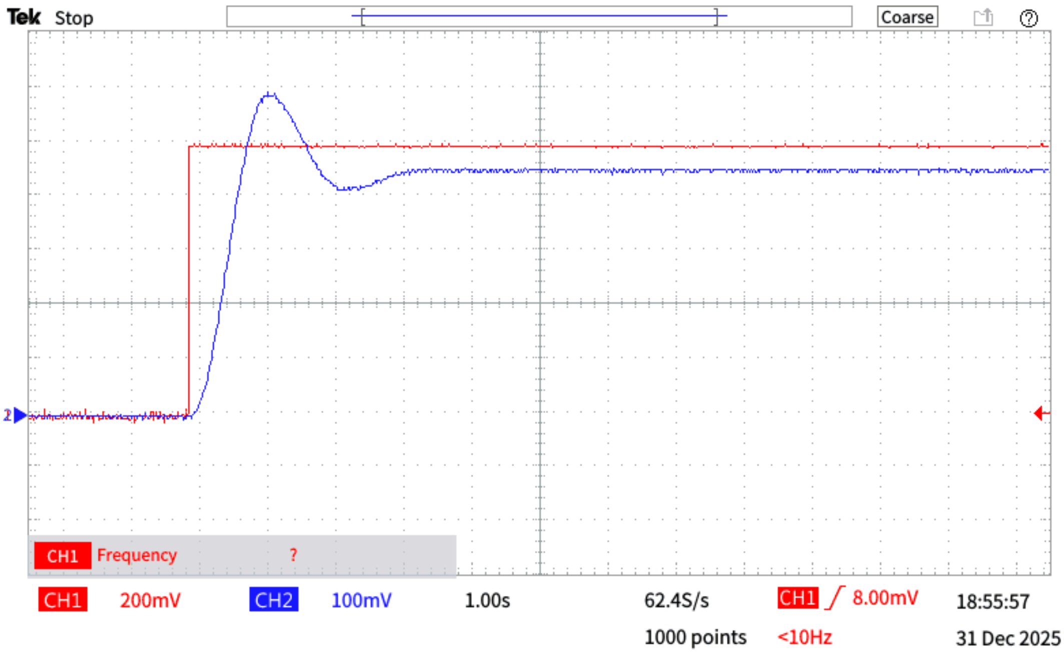

Figure 5: Oscilloscope output showing the angular output response for an amplifier gain of 3.3 (feedback resistor = 330 kΩ).

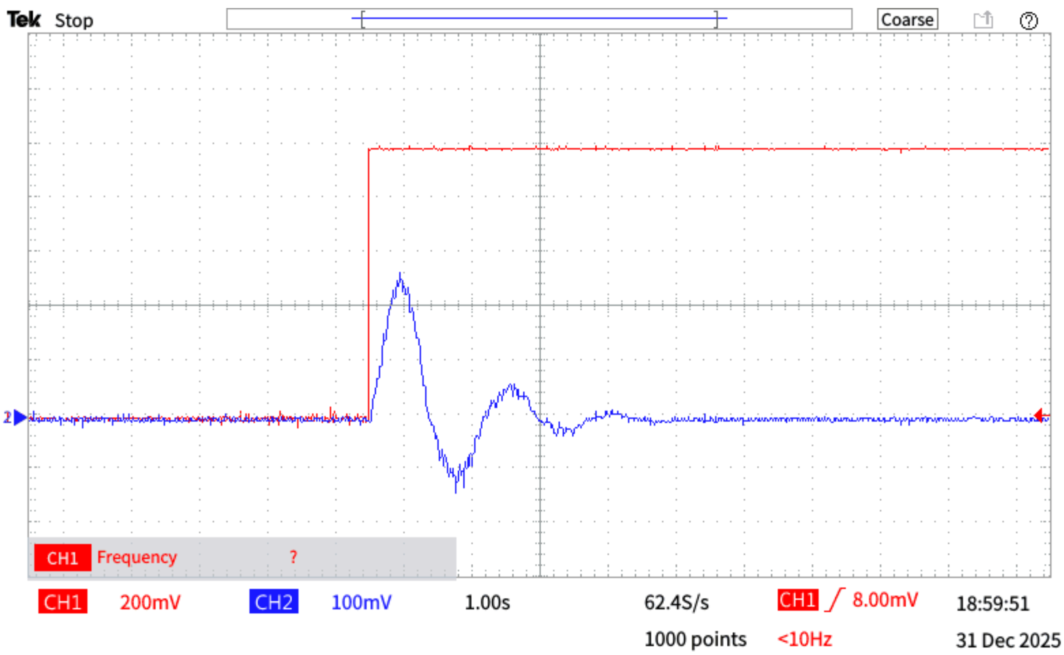

Figure 6 : Oscilloscope output showing the speed output response for an amplifier gain of 3.3 (feedback resistor = 330 kΩ).

v. Observe the the effect of gain by setting the amplifier feedback resistor to 1 MΩ (gain = 10).

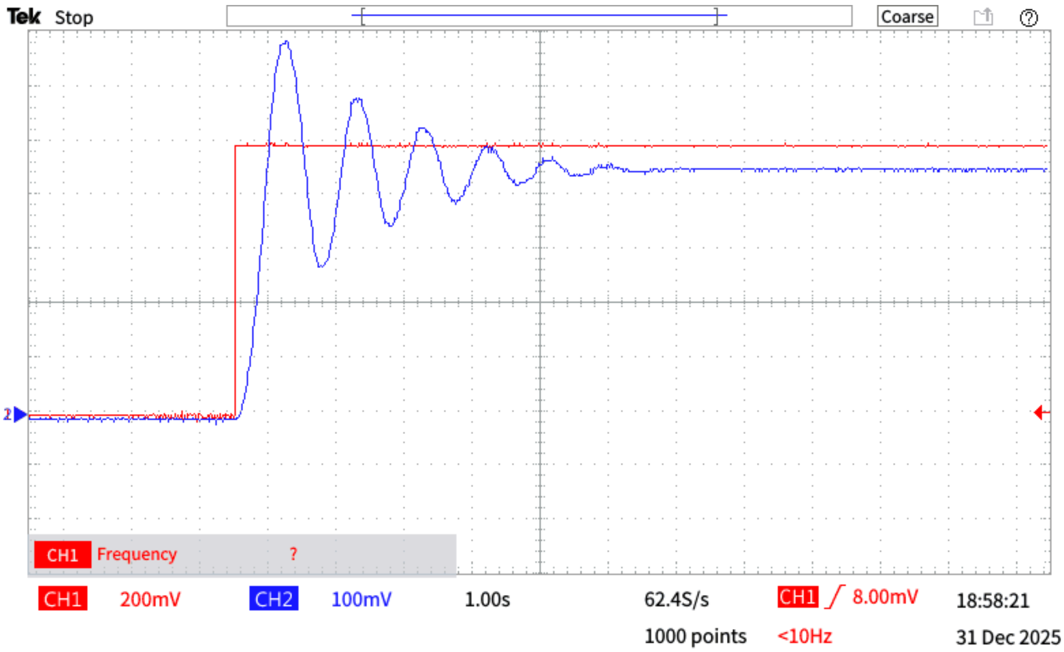

Figure 7 : Oscilloscope output showing the angular output response for an amplifier gain of 10 (feedback resistor = 1MΩ).

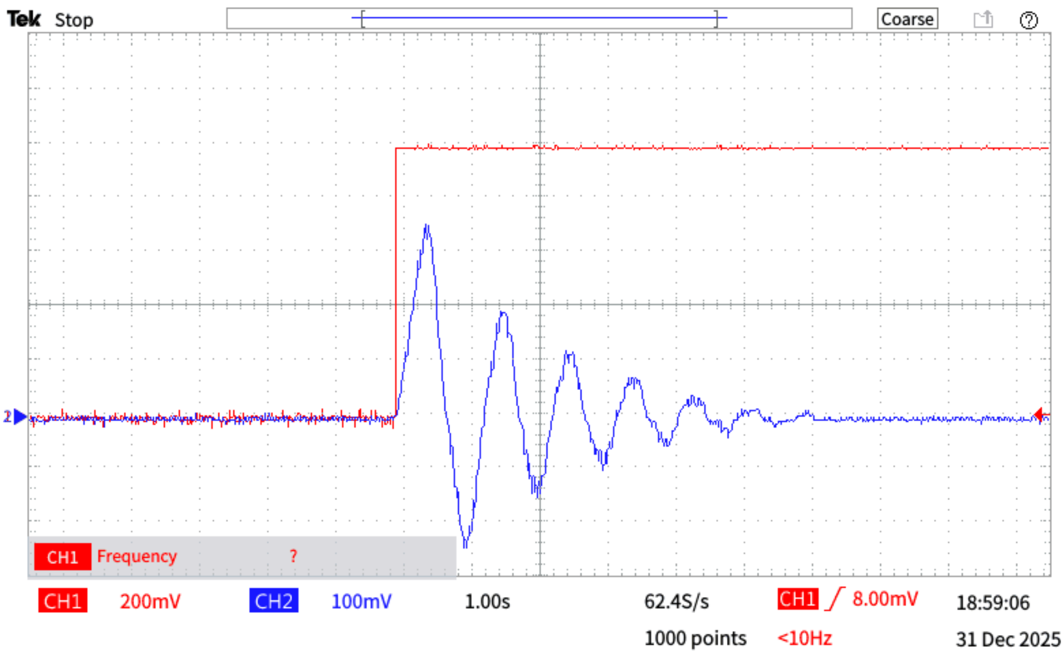

Figure 8 : Oscilloscope output showing the speed output response for an amplifier gain of 3.3 (feedback resistor = 330 kΩ).

Vi. Compare your results.

When the feedback amplification gain is set to 1, the system shows a highly damped response with no overshoot. However, the response is relatively slow, with a longer rise and settling time. Increasing the gain to 3.3 makes the system underdamped. This results in a faster response with a reduced rise time, but introduces a moderate level of oscillation and overshoot.

When the gain is further increased to 10, the system becomes highly underdamped and operates close to instability. Although the response becomes faster with a shorter settling time, the oscillations and overshoot increase significantly, which negatively affects system stability.

2. Velocity Feedback: Assignment 7,

a. Practical 7.1: Simple Velocity Feedback

iii. Observe Compare the effect of the velocity feedback on transient response, when the gain is increased.

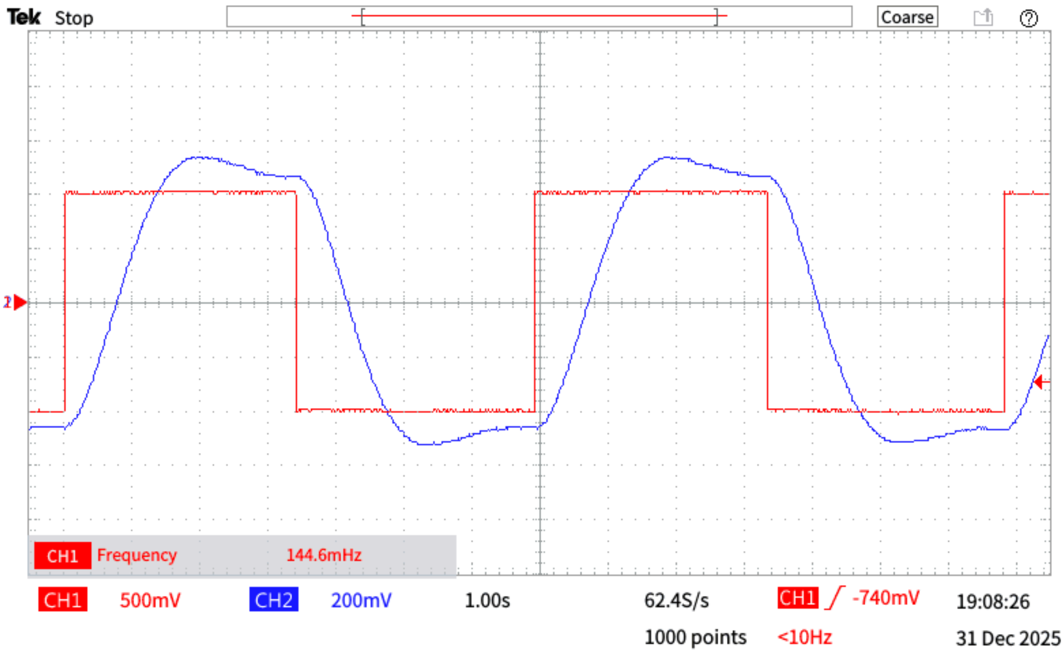

Figure 9 : Transient response of the system with velocity feedback gain set to 0.

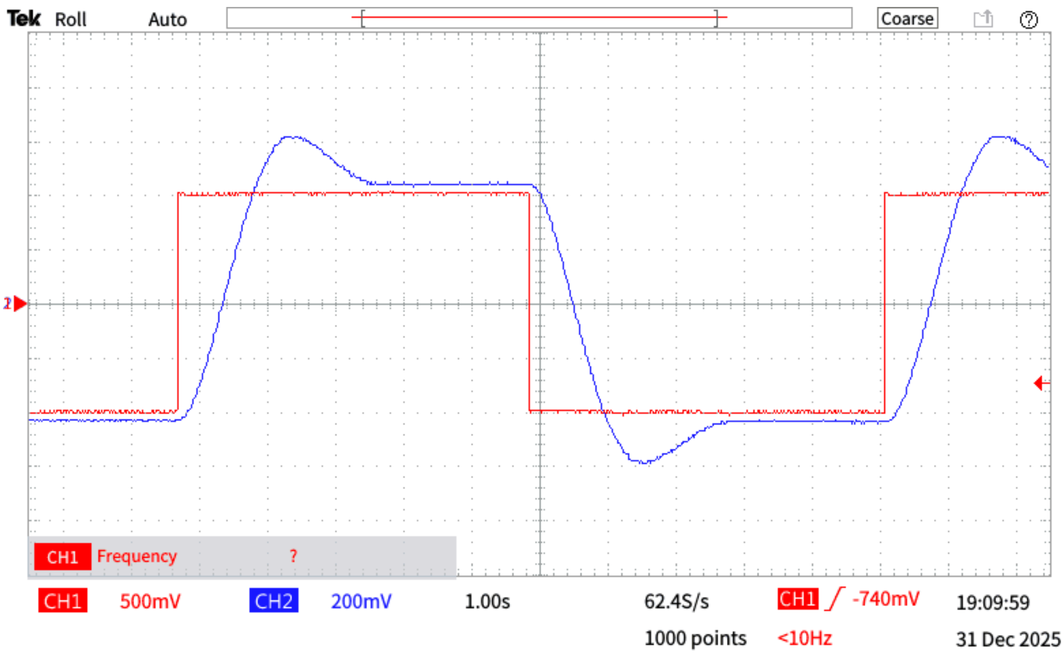

Figure 10 : Transient response of the system with velocity feedback gain set to 50.

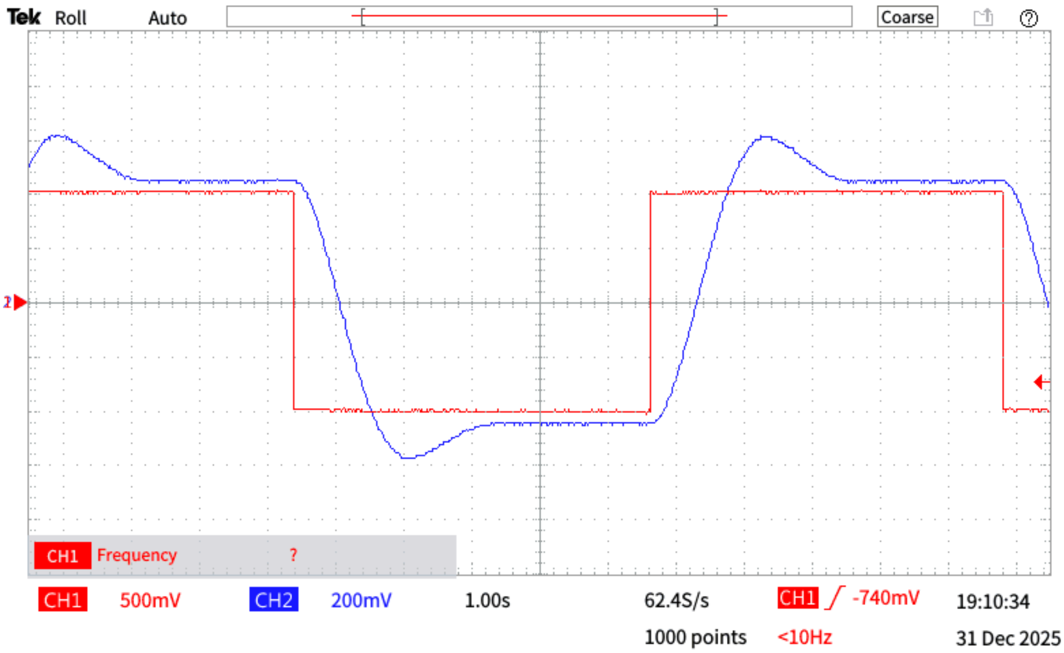

Figure 11 : Transient response of the system with velocity feedback gain set to 100.

When positive velocity feedback is applied, increasing the gain significantly reduces system stability. Even at moderate gain values, the system exhibits large overshoot, making positive velocity feedback unsuitable for stable operation.

iv. What happen when the polarity of the velocity feedback is reversed?

Reversing the feedback polarity applies negative velocity feedback to the closed-loop system. This improves stability compared to positive feedback, allowing higher gain to reduce overshoot. As velocity feedback increases, the system becomes overdamped, while higher gain shortens the rise and settling times, producing a faster response.

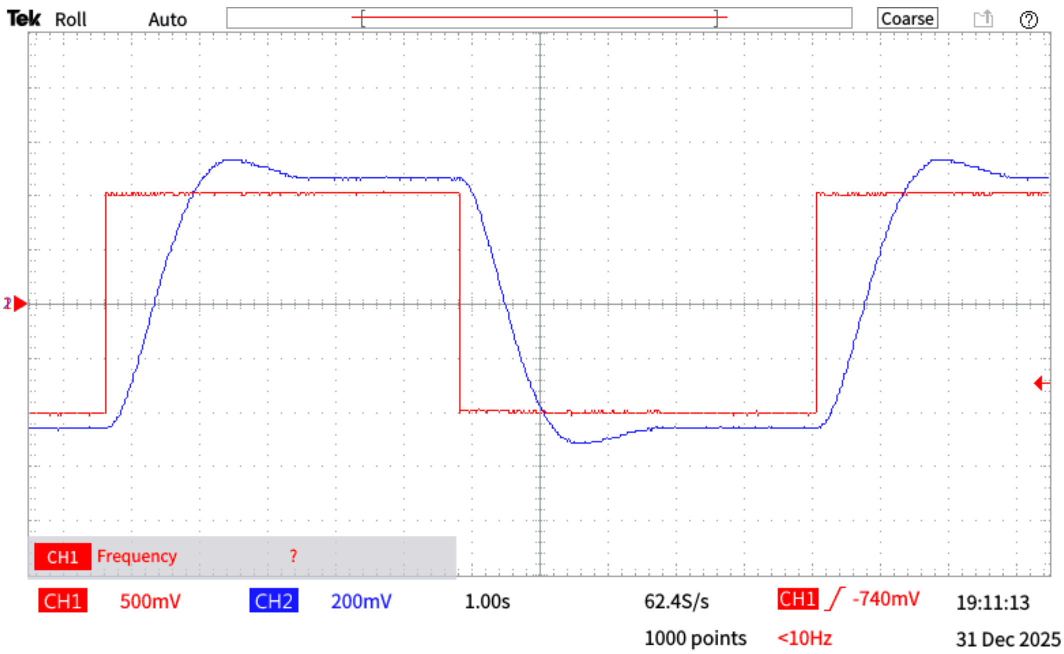

Figure 12 : Transient response of the system with reversed velocity feedback polarity at a gain of 100.

5. Following Error: Assignment 8,
   a. Practical 8.1: Following Error
      vi. Describe how to observe the following error in X-Y mode in the oscilloscope.

The reference input is applied to the X channel and the system output to the Y channel of the oscilloscope to observe the following error in X–Y mode. In this mode, the output is plotted directly against the input. A perfect 45° straight line indicates exact tracking, while any deviation from this line represents a following error.

vii. Compare the results when,

a. input & output resistance is 100 Ω .

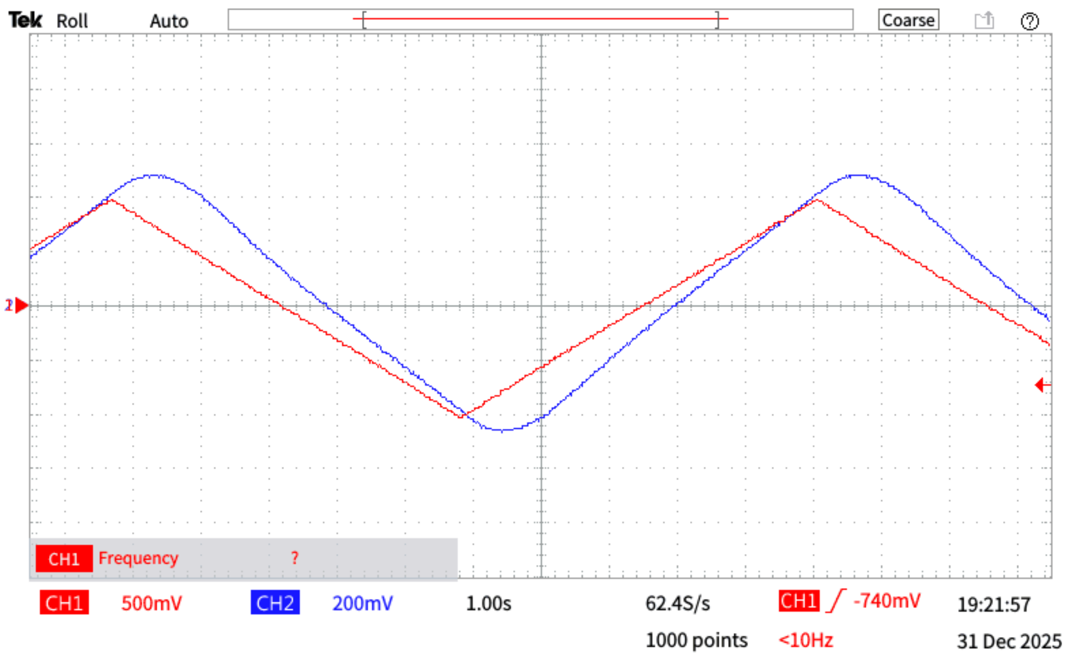

Figure 13 :Time-domain oscilloscope output showing the system response with input and output resistances of 100 kΩ.

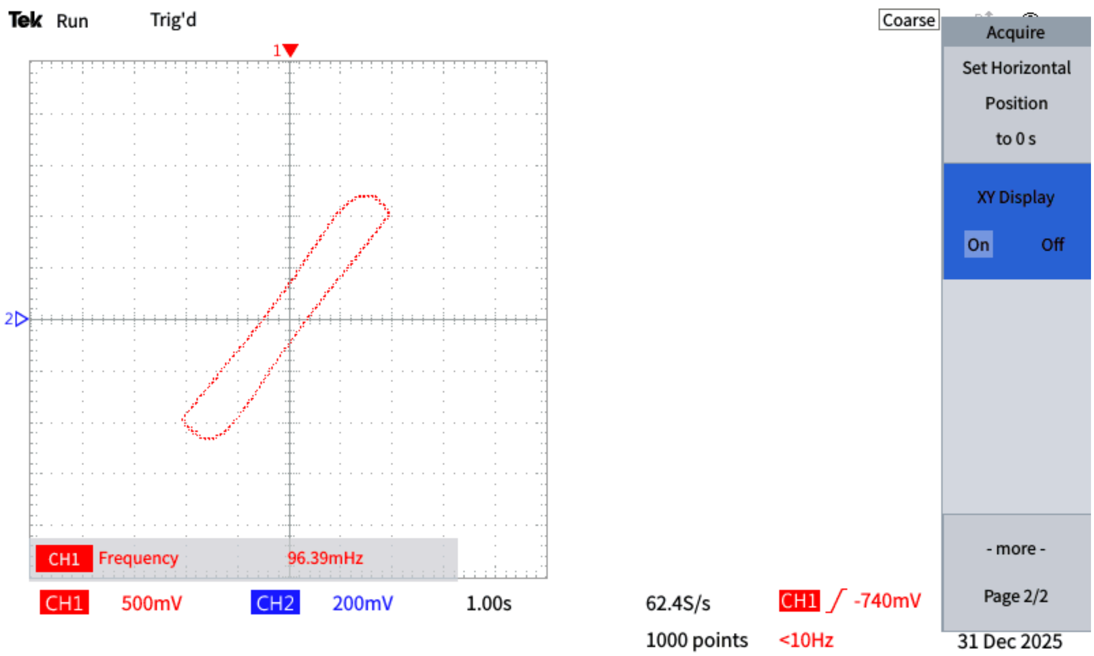

Figure 14 :Error observation in X–Y mode of the oscilloscope with input and output resistances set to 100 kΩ.

b. input $2 \times 100\ \Omega$ in parallel & output is $100\ k\Omega$.

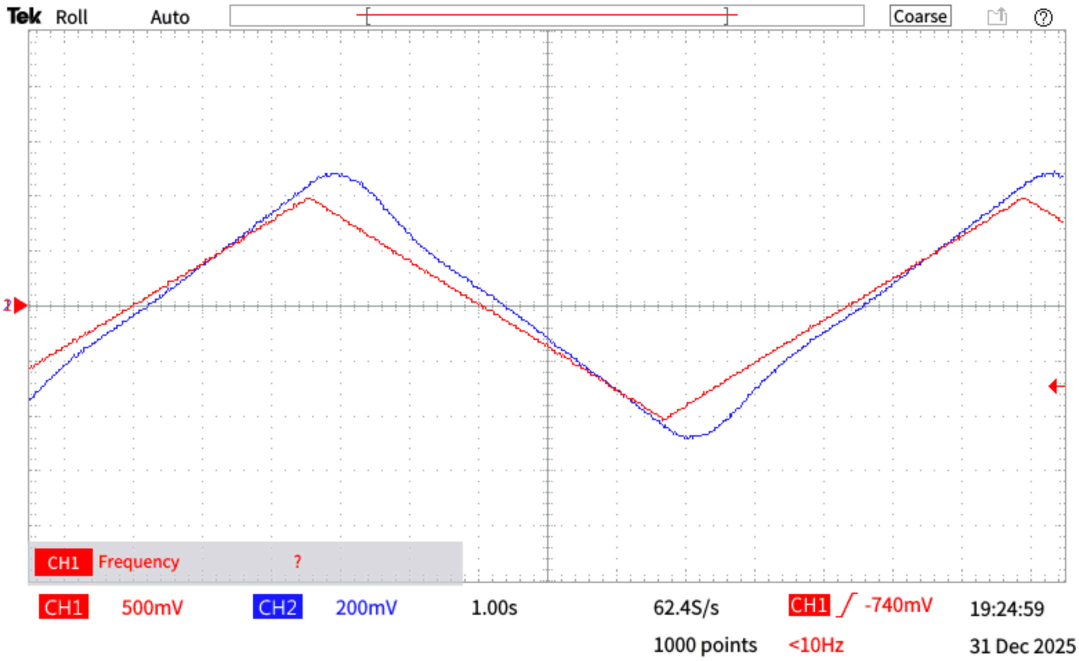

Figure 15 :Time-domain oscilloscope output showing the system response with input $2 \times 100\ \Omega$ in parallel & output is $100\ \Omega$.

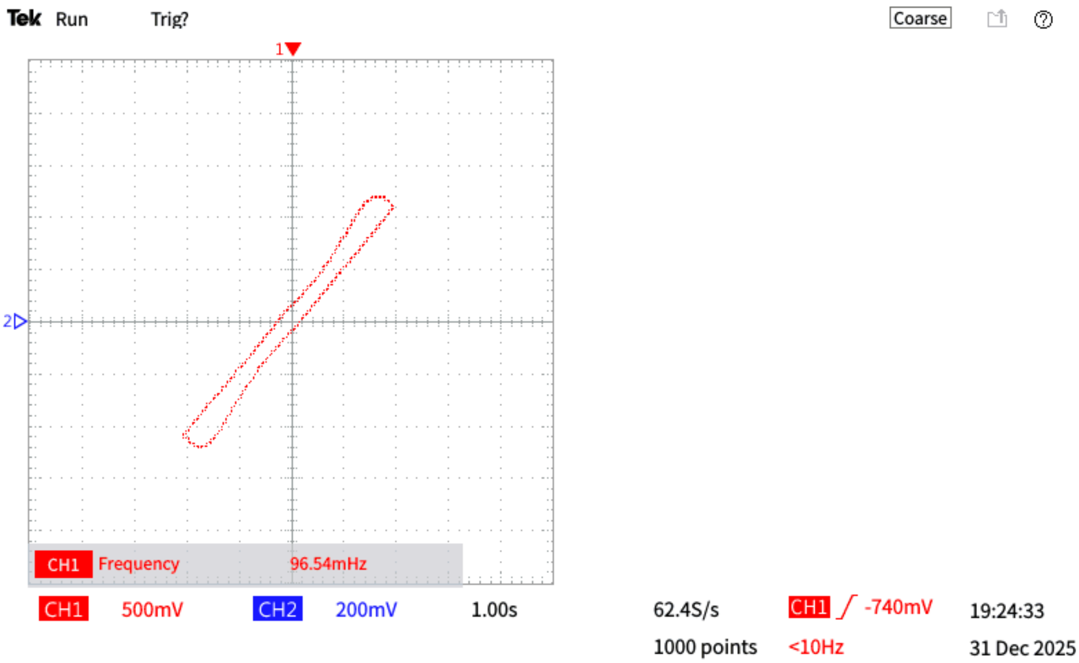

Figure 16 :Error observation in X–Y mode of the oscilloscope with input $2 \times 100\ \Omega$ in parallel & output is $100\ \Omega$.

c. input 100 Ω & output is 500 Ω.

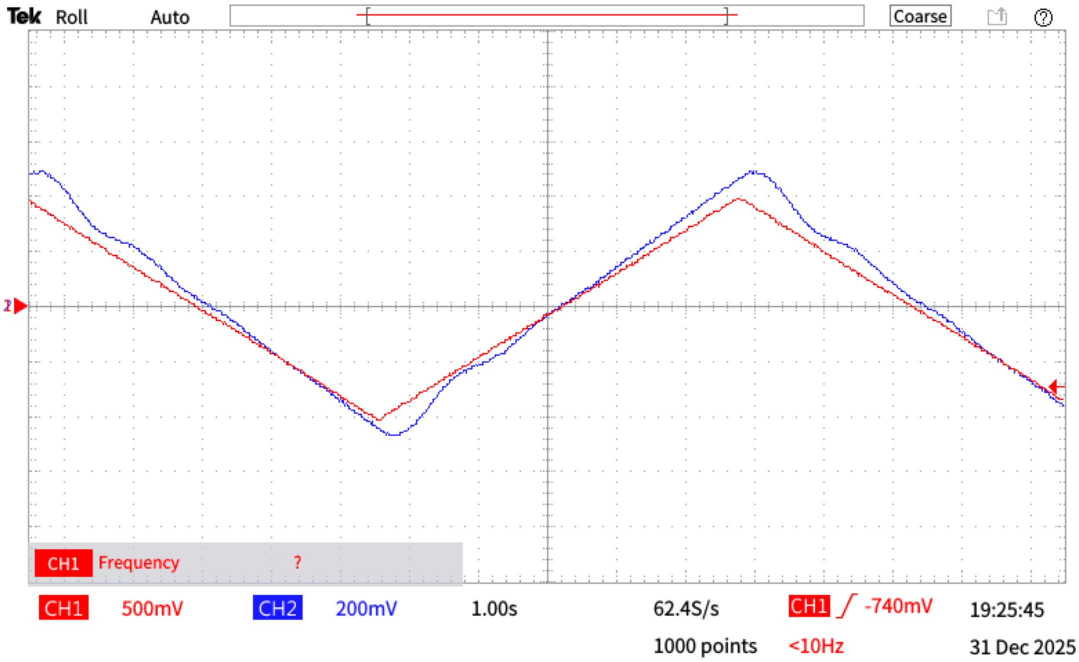

Figure 17 :Time-domain oscilloscope output showing the system response with input 100 Ω & output is 500 Ω.

The data show that the following error decreases as the feedback gain increases. This is because, for a given speed, the error is inversely proportional to the gain—doubling the gain roughly halves the error. However, higher gain also makes the system more oscillatory, indicating a deterioration of the transient response.

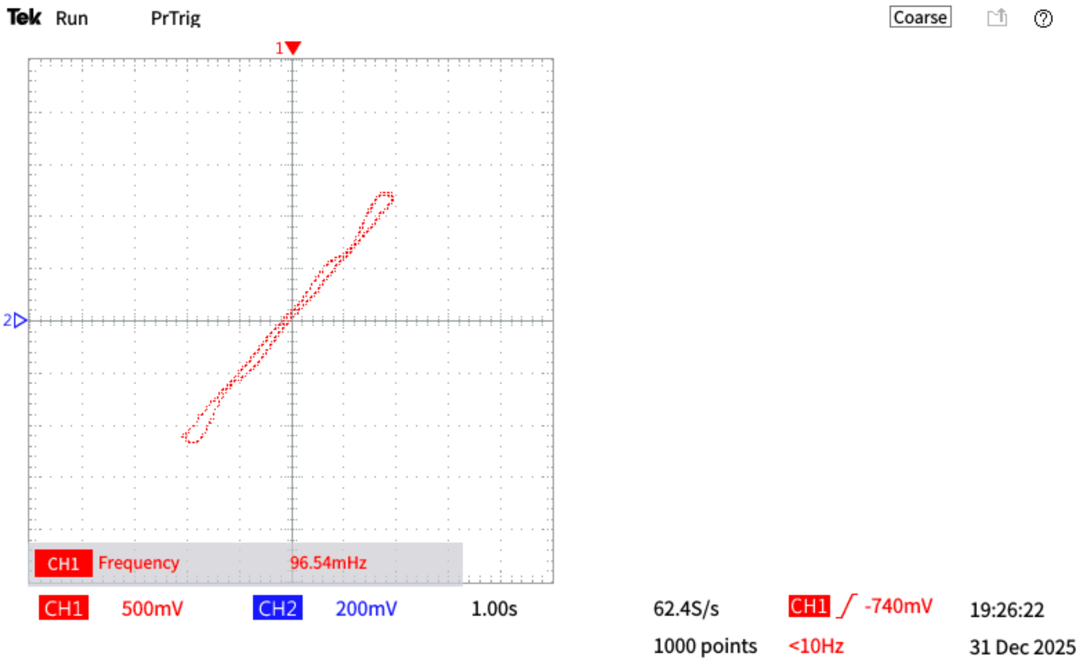

Figure 18 :Error observation in X–Y mode of the oscilloscope with input 100 Ω & output is 500 Ω.

b. Practical 8.2. Velocity Feedback

i. What are the effects of velocity feedback on following error compare the results with previous step (practical 7.1).

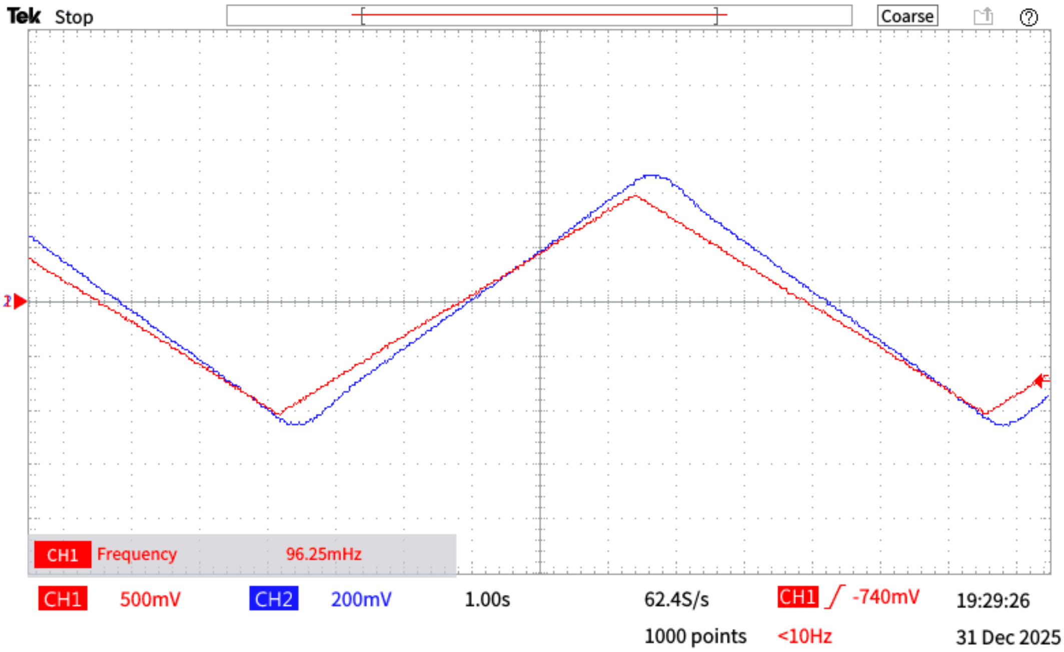

Figure 19: Effect of velocity feedback on following error observed in time-domain using the oscilloscope

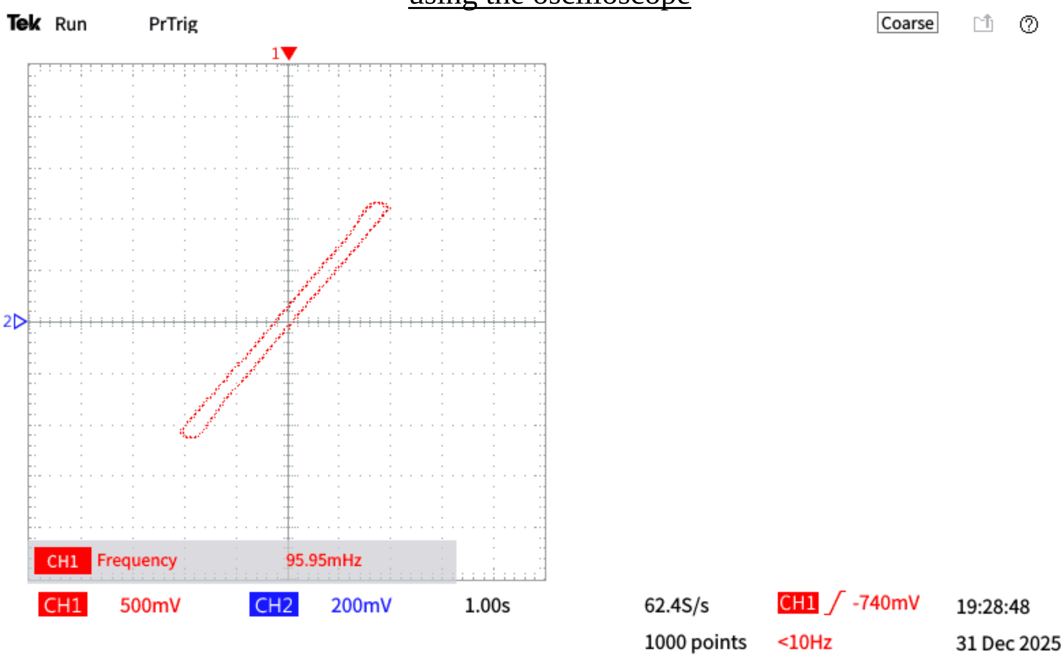

Figure 20: Effect of velocity feedback on following error observed in X–Y mode of the oscilloscope

Increasing the amplifier gain reduces the following error, which helps the system track oscillating input signals more accurately. However, when velocity feedback increases the step response transient, the transient component of the following error also increases, leading to a higher overall following error.

4. Unstable System: Assignment 9,
   a. Practical 9.1: Additional Time Constant
      v. Using the oscilloscope observe the time constant in X-Y mode as well as X-T, Y-T mode.

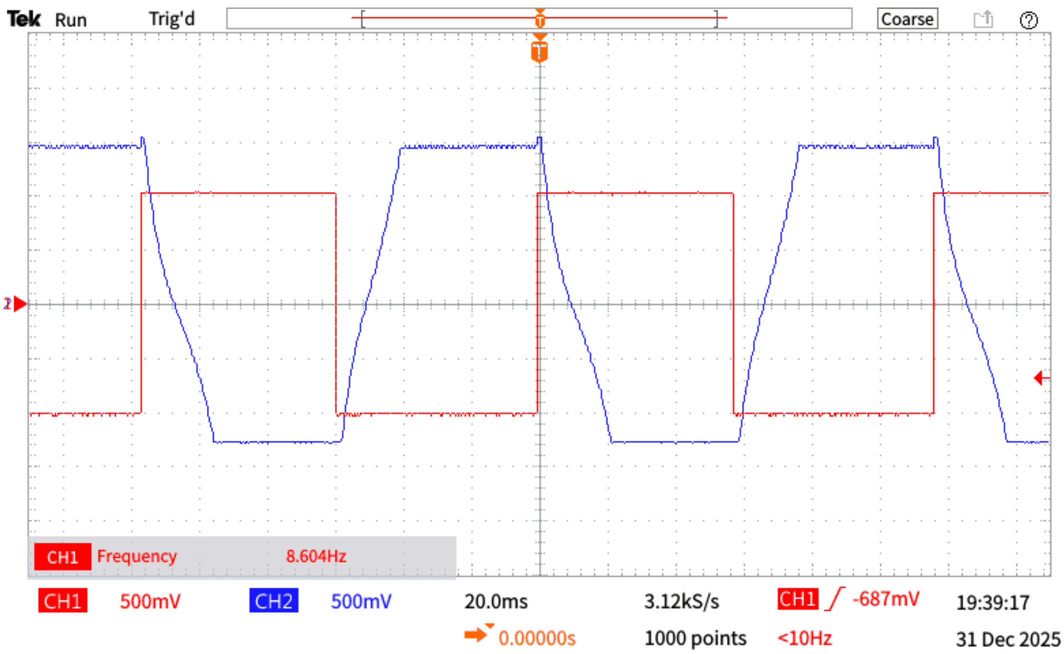

Figure 21: Observation of the system time constant in X–T/Y–T mode using a 1 MΩ resistor.

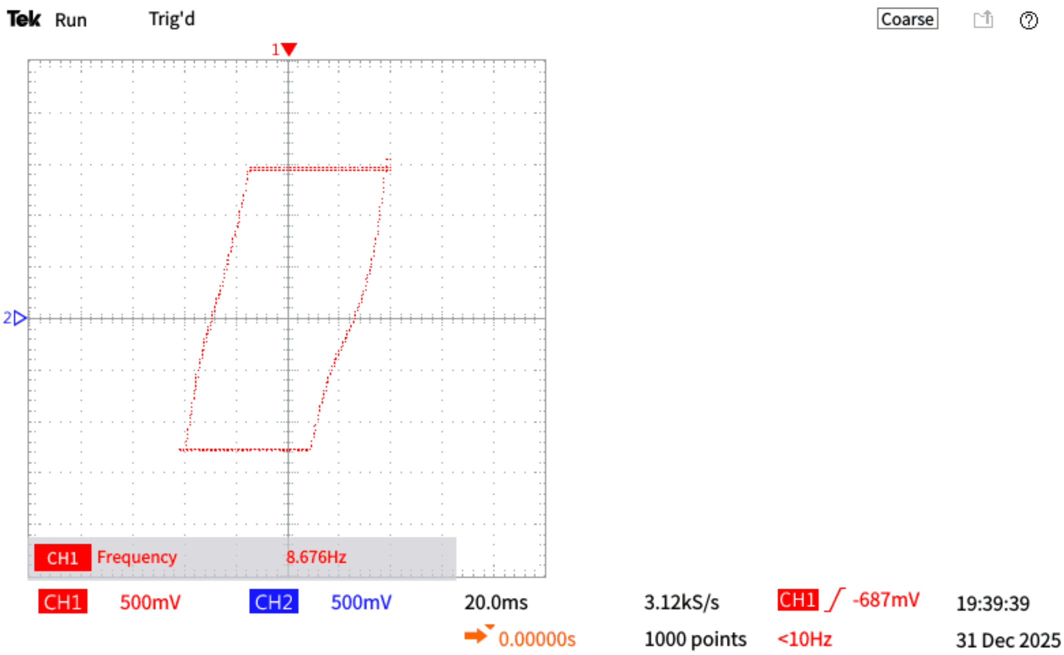

Figure 22: Observation of the system time constant in X–Y mode using a 1 MΩ resistor.

iii. What happen to the time constant when 1 Ω resistor replaced by,

a. $0k\Omega$

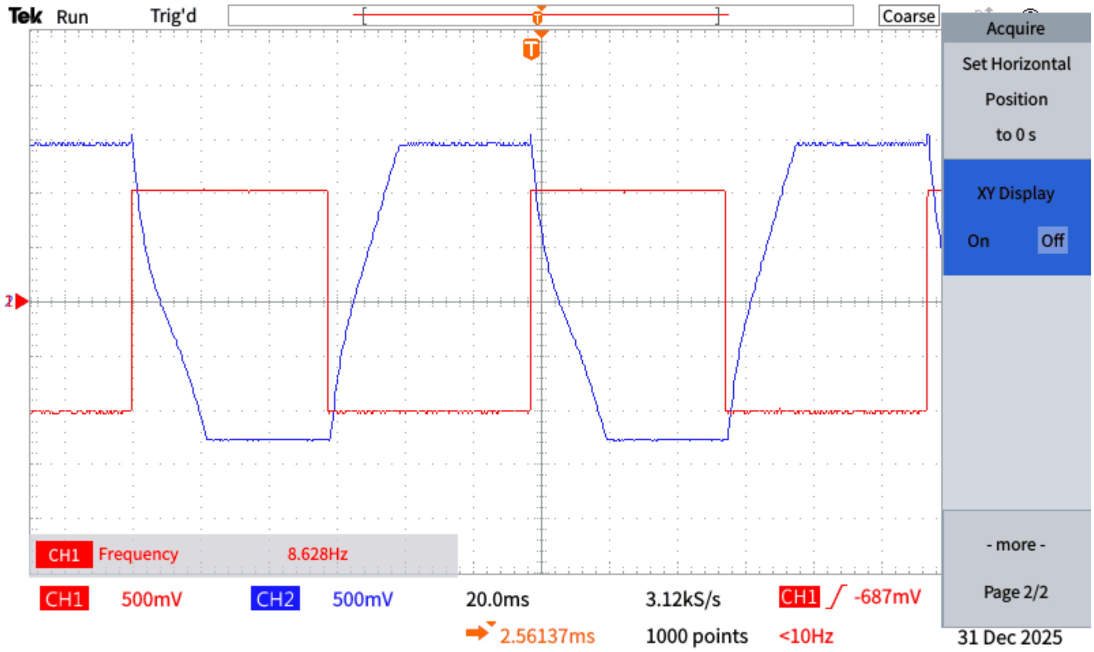

Figure 23: Observation of the system time constant in X–T/Y–T mode using a 330kΩ resistor.

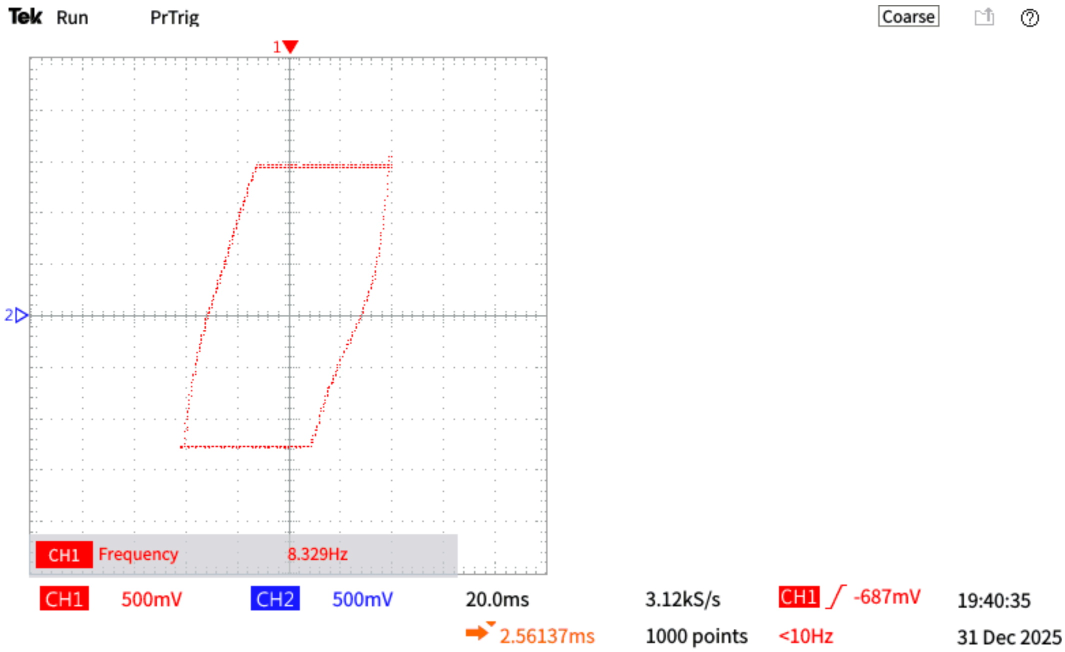

Figure 24: Observation of the system time constant in X–Y mode using a 330kΩ resistor.

b. $100k\Omega$

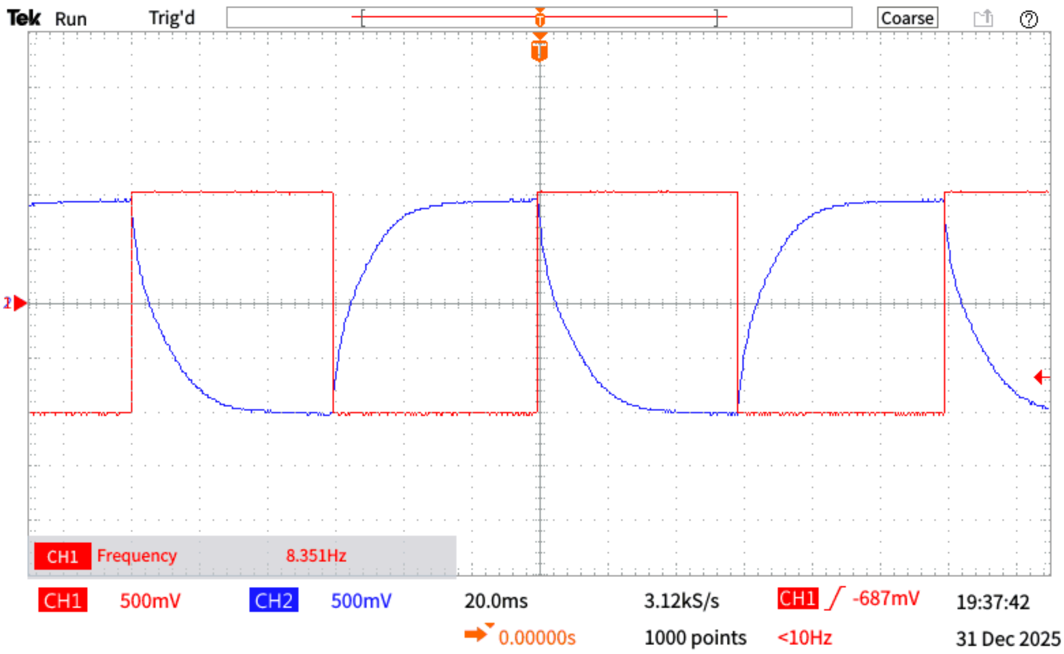

Figure 25: Observation of the system time constant in X–T/Y–T mode using a 100kΩ resistor.

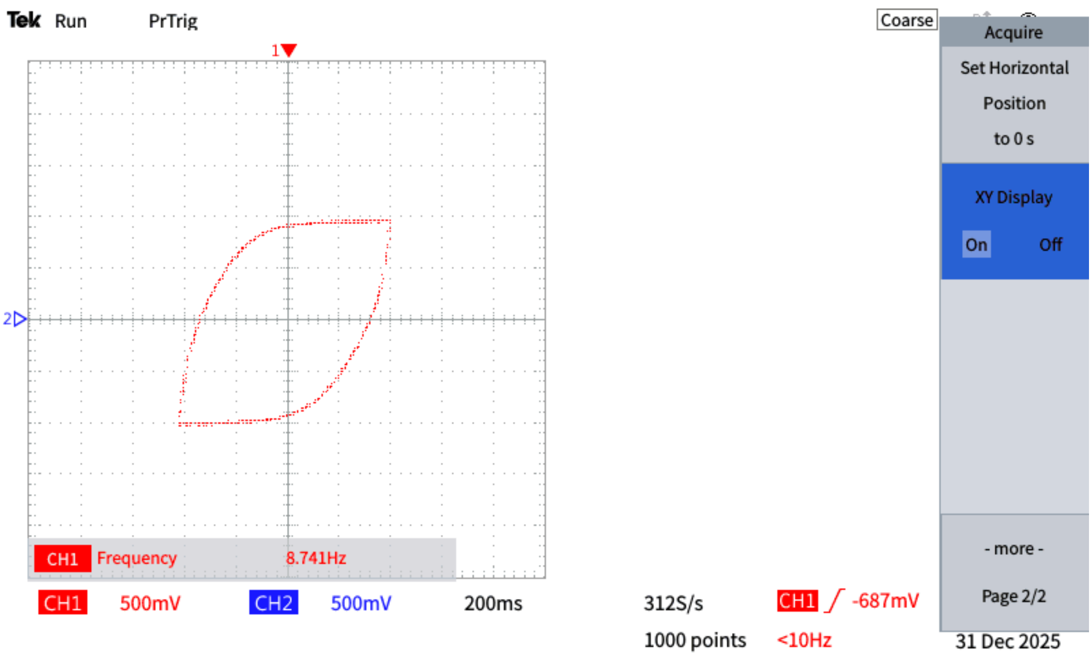

Figure 26: Observation of the system time constant in X–Y mode using a 100kΩ resistor.

As the gain increases, the X–T and Y–T plots show a reduced transient response, indicating a smaller time constant. At a resistance of 100 kΩ, the time constant reaches its minimum. Although a lower time constant normally results in a faster response, this is not observed here because the gain decreases as the resistance is reduced

b. Practical 9.2: Unstable System

i. Using the oscilloscope observe the time constant in X-Y mode as well as X-T, Y-T mode.

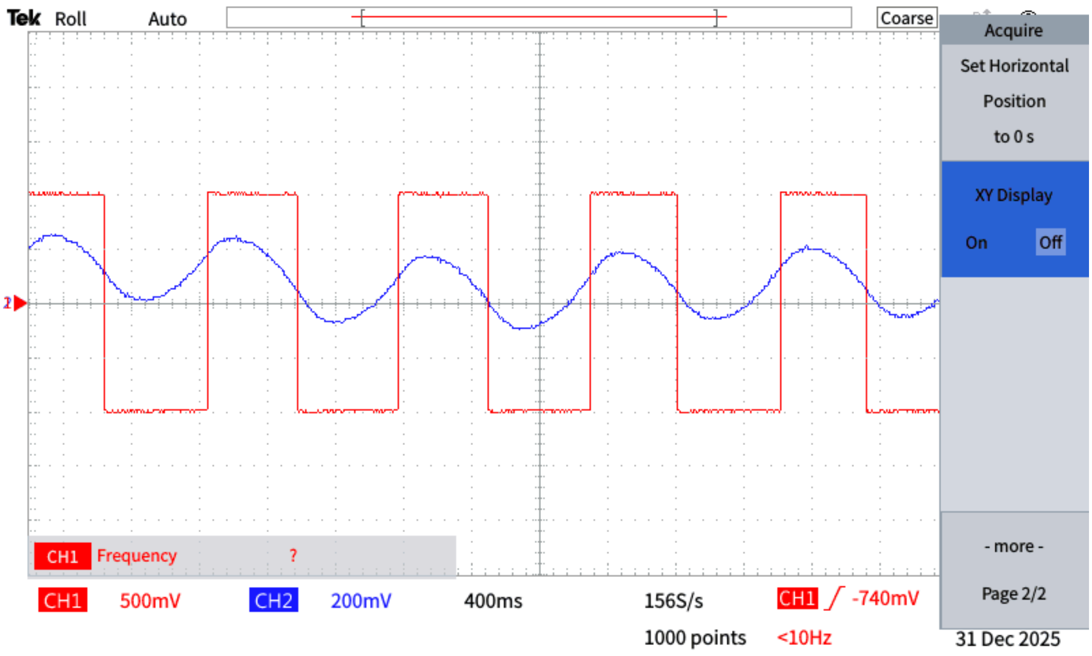

Figure 27 :Observation of the system time constant in X–T/Y–T mode using a 100kΩ resistor.

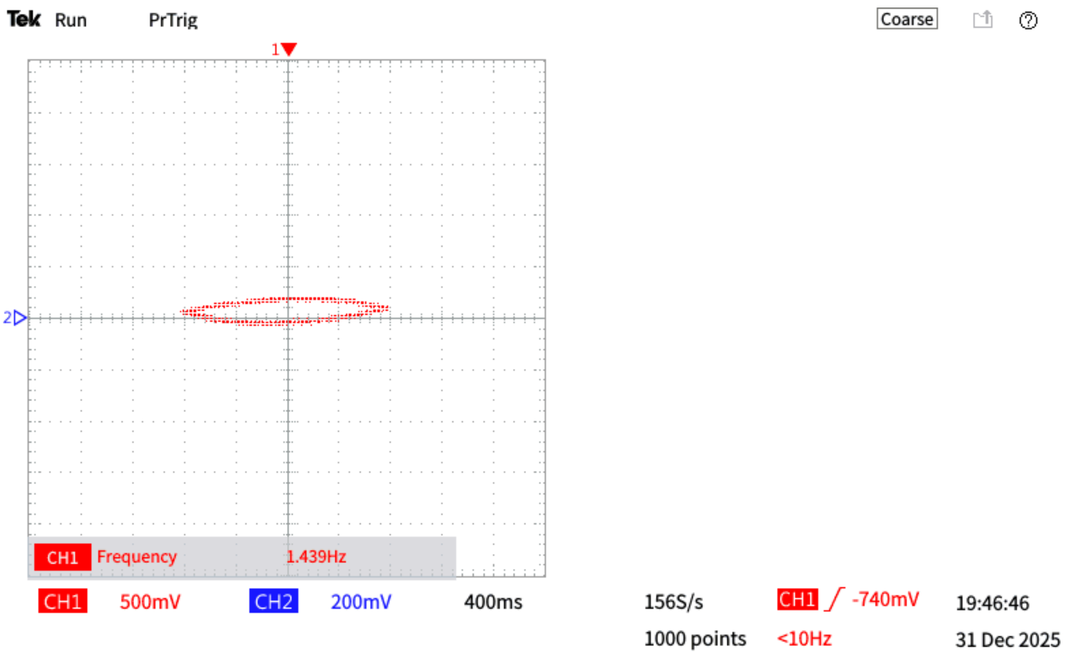

Figure 28 : Observation of the system time constant in X–Y mode using a 100kΩ resistor.

ii. Using the oscilloscope observe the time constant in X-Y mode as well as X-T, Y-T mode.

a. $0k\Omega$

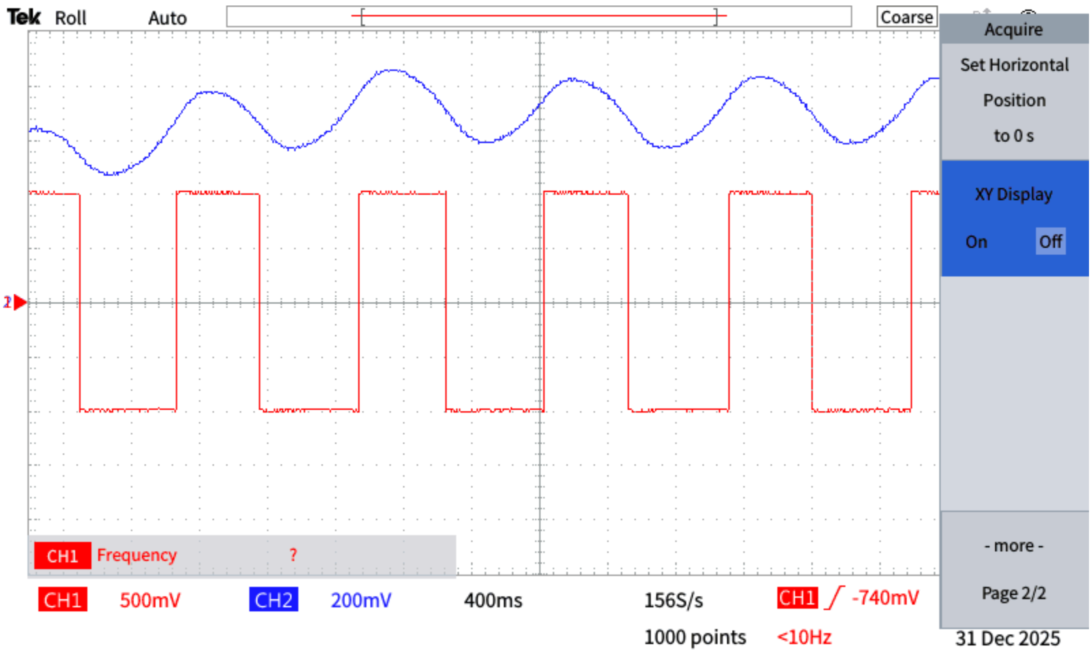

Figure 29 :Observation of the system time constant in X–T/Y–T mode using a 330kΩ resistor.

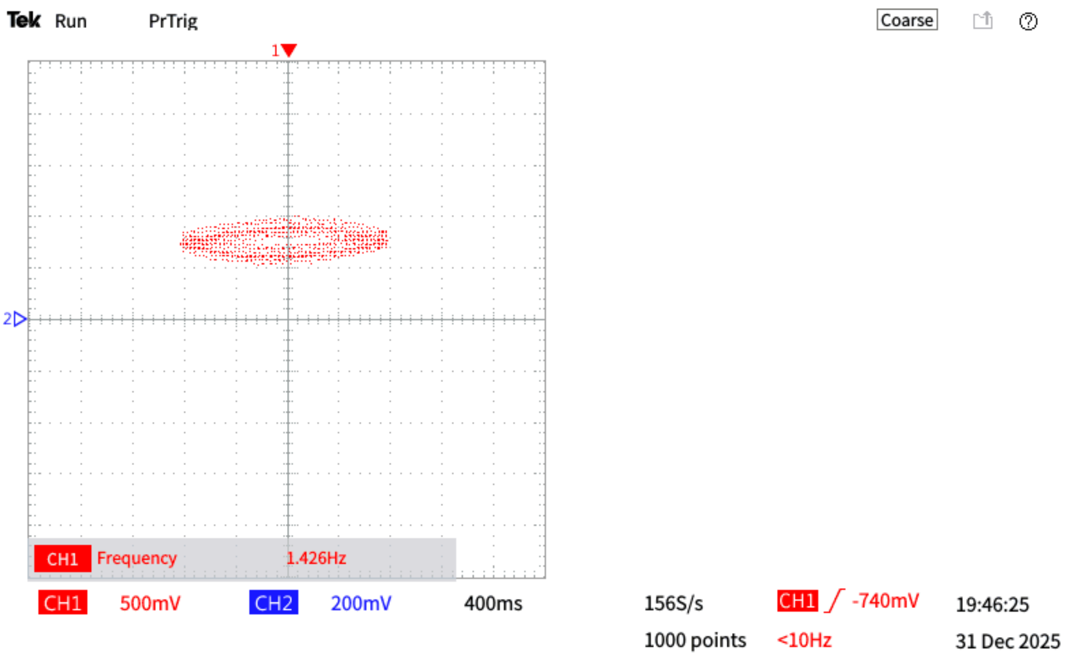

Figure 30 : Observation of the system time constant in X–Y mode using a 330kΩ resistor.

b. $1M\Omega$

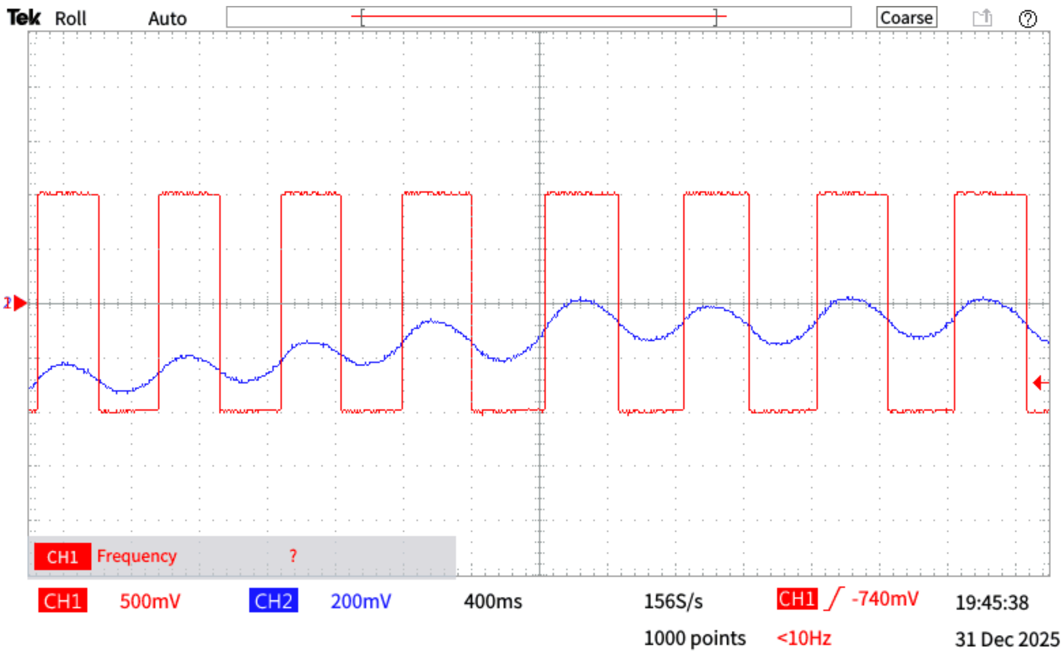

Figure 31 :Observation of the system time constant in X–T/Y–T mode using a 1 MΩ resistor.

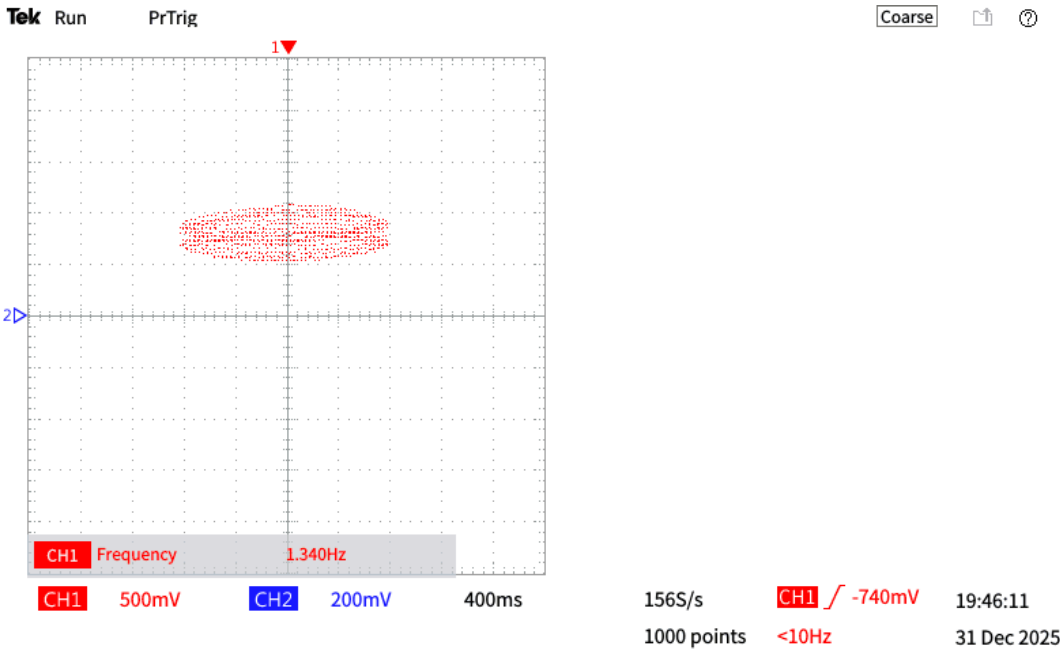

Figure 32 : Observation of the system time constant in X–Y mode using a 1 MΩ resistor.

5. Closed Loop Speed Controls: Assignment 10,
   a. Practical 10.1: Closed-loop Speed Control
      vi. Plot graphs for six brake settings with & without Velocity feedback for Gain=1 and Gain=10.

Table 1 : Motor speed response for six brake settings with and without velocity feedback at gains of 1 and 10.

Brake No	Motor speed / (rpm)			
	With feedback		Without feedback	
	For Gain = 1	For Gain = 10	For Gain = 1	For Gain = 10
1	49.4	69.7	68.7	68.0
2	47.5	63.6	64.4	60.6
3	44.0	55.5	57.2	46.9
4	38.2	43.3	44.8	40.3
5	34.3	34.5	36.4	33.3
6	31.5	30.3	33.0	30.1
7	29.3	29.6	29.6	29.0

Table 2 : Variation of Speed against Brake Settings with & without Velocity Feedback for Gain = 1

Brake Setting	Speed / (rpm) Without Velocity Feedback	Speed / (rpm) With Velocity Feedback
1	49.4	68.7
2	47.5	64.4
3	44.0	57.2
4	38.2	44.8
5	34.3	36.4
6	31.5	33.0
7	29.3	29.6

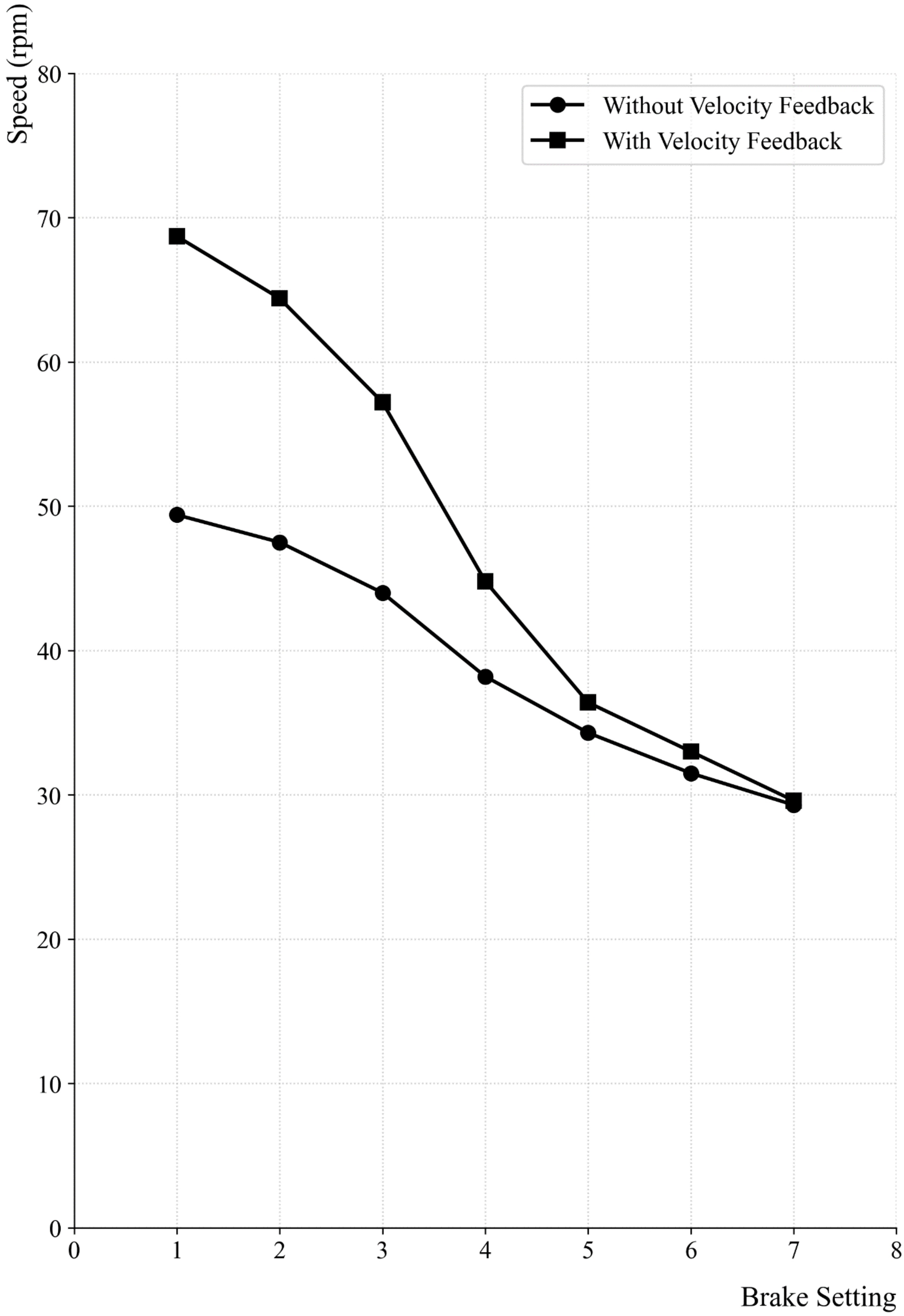

FIGURE 33 : SPEED VS BRAKE SETTINGS WITH & WITHOUT VELOCITY FEEDBACK FOR GAIN = 1

Table 3: Variation of Speed against Brake Settings with & without Velocity Feedback for Gain = 10

Brake Setting	Speed / (rpm) Without Velocity Feedback	Speed / (rpm) With Velocity Feedback
1	69.7	68.0
2	63.6	60.6
3	55.5	46.9
4	43.3	40.3
5	34.5	33.3
6	30.3	30.1
7	29.6	29.0

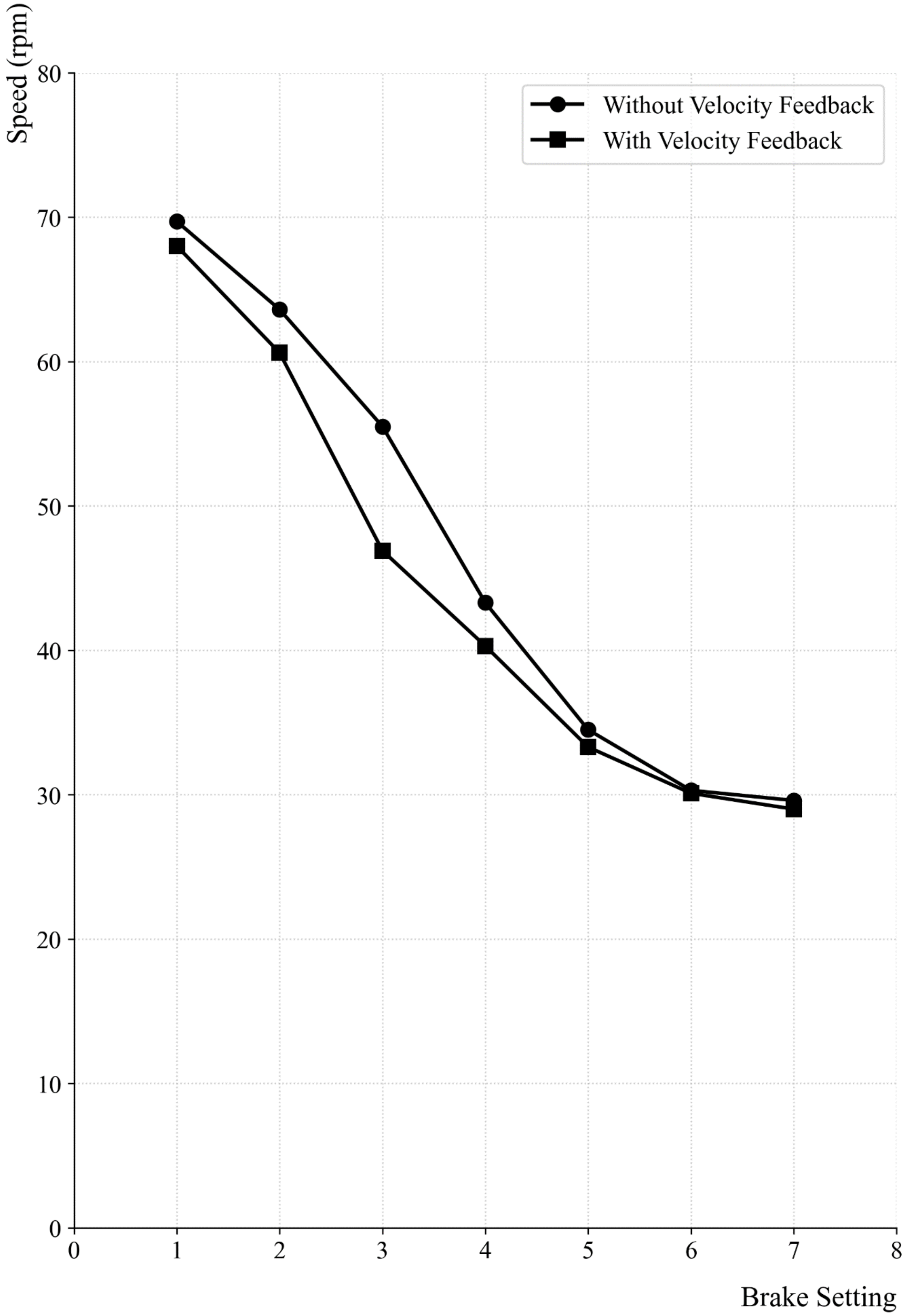

FIGURE 34 : SPEED VS BRAKE SETTINGS WITH & WITHOUT VELOCITY FEEDBACK FOR GAIN = 10

REFERENCES

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3. S. Sundaram, *ECE 380: Control Systems Course Notes*, Purdue University. https://engineering.purdue.edu/~sundara2/misc/ece380_notes.pdf [Accessed: Jan. 19, 2026].