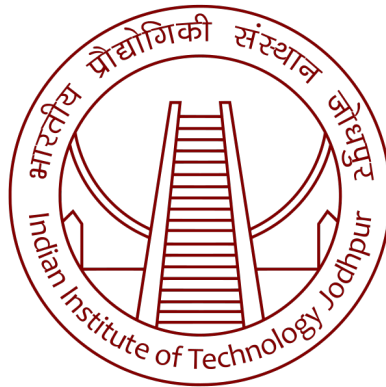


EEL3040

Control System



॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

Lab-7 Report

By-B22EE024

Dhyey Findoriya

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Objective

a) Aim

- To verify the effect of input waveform, loop gain, and system type upon steady-state errors.

b) Apparatus

- MATLAB, Simulink, and the Control System Toolbox.

Theory

a) Description

- Steady-state error is defined as the difference between the input (command) and the output of a system in the limit as time goes to infinity (i.e. when the response has reached steady state). The steady-state error will depend on the type of input (step, ramp, etc.) as well as the system type (0, I, or II).
- Steady-state error can be calculated from the open- or closed-loop transfer function for unity feedback systems.

$$E(s) = R(s) - Y(s)$$

$$H(s) = 1 \text{ (Unity Feedback)}$$

Steady state error can be calculated by:

$$e_{ss} = \lim_{s \rightarrow 0} sE(s) = \lim_{s \rightarrow 0} \frac{sR(s)}{1 + G(s)}$$

Input Signals

a) Step Input = $1/s$

$$e_{ss} = \frac{1}{1 + \lim_{s \rightarrow 0} G(s)} = \frac{1}{1 + K_p}$$

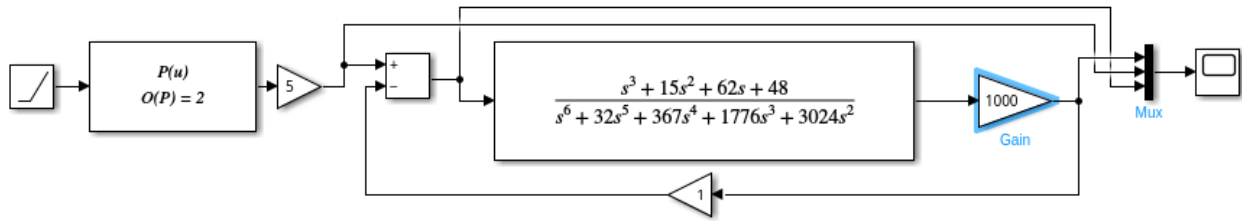
b) Ramp Input = $1/s^2$

$$e_{ss} = \frac{1}{1 + \lim_{s \rightarrow 0} sG(s)} = \frac{1}{1 + K_p}$$

c) Parabolic Input = $1/s^3$

$$e_{ss} = \frac{1}{1 + \lim_{s \rightarrow 0} s^2 G(s)} = \frac{1}{1 + K_p}$$

System Design



Calculation

Calculation

(i) $E(s) = R_s \cdot \frac{1}{1+G} = \frac{1}{s} \cdot \frac{1}{1+\frac{k}{s+a}}$

$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = \frac{s+a}{s+a}$

$E(s) = \frac{a}{a+k}$

(ii) $E(s) = \lim_{s \rightarrow 0} s \cdot \frac{1}{1+\frac{k}{s+a}} \times \frac{1}{s}$

$\lim_{s \rightarrow 0} \frac{s+a}{s^2+as+k} = \infty$

(iii) $E(s) = \lim_{s \rightarrow 0} s \cdot E(s)$

$\frac{1}{s^3} \cdot \frac{1}{1+\frac{k}{s+a}}$

$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = \infty$

(iv) $E(s) = \frac{1}{s} \cdot \frac{1}{1+\frac{k}{s+a}} = \frac{1}{s} \cdot \frac{s(s+a)}{s(s+a)+k}$

$E(s) = \lim_{s \rightarrow 0} s \cdot \frac{1}{s} \cdot \frac{s(s+a)}{s(s+a)+k} = 0$

$$(v) \quad \xi(s) = \frac{1}{s^2} \cdot \frac{1}{1+k} = \frac{1}{s^2} \cdot \frac{s(s+a)}{s(s+a)+k}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \xi(s) = \frac{a}{k}$$

$$(vi) \quad \xi(s) = \frac{1}{s^3} \cdot \frac{1}{1+k} = \frac{1}{s^3} \cdot \frac{s(s+a)}{s(s+a)+k}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \cdot \frac{1}{s^3} \cdot \frac{s(s+a)}{s(s+a)+k} = \infty$$

$$(7) \quad \xi(s) = \frac{1}{s^4} \cdot \frac{1}{1+k} = \frac{1}{s^4} \cdot \frac{s^2(s+a)}{s^2(s+a)+k}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \cdot \xi(s) = \frac{s^2(s+a)}{s^2(s+a)+k} = 0$$

$$(8) \quad \xi(s) = \frac{1}{s^2} \cdot \frac{s^2(s+a)}{s^2(s+a)+k}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \xi(s) = \frac{s(s+a)}{s^2(s+a)+k} = 0$$

$$(9) \quad \xi(s) = \frac{1}{s^3} \cdot \frac{s^2(s+a)}{s^2(s+a)+k}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \xi(s) = 0 \quad | \quad k$$

$$(10) \quad \xi(s) = \frac{1}{s} \cdot \frac{s^3(s+9)}{s^3(s+9)+K} \Rightarrow \lim_{s \rightarrow \infty} s \xi(s) = \infty$$

$$(11) \quad \xi(s) = \frac{1}{s^3} \cdot \frac{s^3(s+9)}{s^3(s+9)+K}$$

$$\xi(s) = \lim_{s \rightarrow 0} s \cdot \xi(s) = 0$$

$$(12) \quad \xi(s) = \frac{1}{s^3} \cdot \frac{s^3(s+9)}{s^3(s+9)+K}$$

$$\lim_{s \rightarrow 0} s \cdot \xi(s) = \frac{s^4(s+9)}{s^3(s+9)+K} = 0$$

(6)

$$R(s) = \frac{5}{s}$$

$$R(s) = \frac{5}{s}$$

$$\xi(s) = \frac{5}{s} \cdot \frac{1}{1 + \frac{K(s+6)}{(s+4)(s+7)(s+9)(s+12)}}$$

$$1 + \frac{K(s+6)}{(s+4)(s+7)(s+9)(s+12)}$$

$$(s+4)(s+7)(s+9)(s+12)$$

$$\xi(s) = \lim_{s \rightarrow 0} s \cdot \xi(s)$$

$$= \lim_{s \rightarrow 0} s \cdot \frac{5}{s} \cdot \frac{(s+4)(s+7) \dots (s+12)}{(s+4) \dots (s+12) + K(s+6)}$$

$$(s+4) \dots (s+12) + K(s+6)$$

$$E(s) = \frac{5 \cdot 4 \cdot 7 \cdot 9 \cdot 12}{4 \cdot 7 \cdot 9 \cdot 12 + 6K}$$

$$E(s) = \frac{2520}{2520 + K}$$

$$\Rightarrow R(s) = \frac{5}{s^2}$$

$$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = \frac{1}{s} \cdot \left(\frac{E(s)}{s} \right)$$

$$= \frac{1}{s} \cdot \left(\frac{2520}{2520 + K} \right)$$

$$\lim_{s \rightarrow 0} \frac{1}{s} \left(\frac{1}{s} \right)$$

$$\Rightarrow \infty$$

$$\Rightarrow R(s) = \frac{5}{s^3}$$

$$E(s) = \lim_{s \rightarrow 0} s E(s) = \frac{1}{s^2} \left(\frac{2520}{2520 + K} \right)$$

$$\lim_{s \rightarrow 0} \frac{1}{s^2} \left(\frac{1}{s} \right) \Rightarrow \infty$$

$$(7) \quad R(s) = \frac{5}{s}$$

$$E(s) = \frac{5}{s} \cdot \frac{1}{1 + \frac{K(s+6)(s+8)}{s(s+4)(s+7)(s+9)(s+12)}}$$

$$= \frac{5}{s} \cdot \frac{s(s+4)(s+7)(s+9)(s+12)}{s(s+4)(s+7)(s+9)(s+12) + K(s+6)(s+8)}$$

$$E(s) = \lim_{s \rightarrow 0} s \cdot E(s)$$

$$= \lim_{s \rightarrow 0} \frac{5 \cdot s(s+4) \cdots (s+12)}{s(s+4)(s+7)(s+9)(s+12) + K(s+6)(s+8)}$$

$$E(s) = 0.$$

$$\Rightarrow R(s) = \frac{5}{s^2}$$

$$E(s) = \frac{5}{s^2} \cdot \frac{s(s+4)(s+7)(s+9)(s+12)}{s(s+4)(s+7)(s+9)(s+12) + K(s+6)(s+8)}$$

$$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = \frac{5 \cdot 4 \cdot 7 \cdot 9 \cdot 12 \cdot 12}{K \cdot 60 \cdot 8}$$

$$E(s) = \frac{315}{K}$$

$$\Rightarrow R(s) = \frac{5}{s^3}$$

$$E(s) = \lim_{s \rightarrow 0} = \frac{1}{s} \cdot \left[\frac{E(s)}{s^2} \right]$$

$$E(s) = \lim_{s \rightarrow 0} \frac{1}{s} \left(\frac{315}{K} \right)$$

$$E(s) \rightarrow \infty$$

(8)

~~$R(s) = \frac{5}{s}$~~

$$R(s) = \frac{5}{s}$$

$$E(s) = \frac{5}{s} \cdot \frac{s^2(s+4)(s+7)(s+9)(s+12)}{s^2(s+4)(s+7)(s+9)(s+12) + K(s+1)(s+6)(s+8)}$$

$$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = 0$$

$$R(s) = \frac{5}{s^2}$$

$$E(s) = \frac{5}{s^2} \cdot \frac{\cancel{s^2}(s+4) \cdots (s+12)}{\cancel{s^2}(s+4) \cdots (s+12) + K(s+1)(s+6)(s+8)}$$

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$$E(s) = \lim_{s \rightarrow 0} s E(s) = \frac{s \cdot s \cdot (s+4) \cdot \dots (s+12)}{s^2(s+4) \cdot \dots (s+12) + K(s+1)(s+6)(s+8)}$$

$$E(s) = 0$$

$$R(s) \approx \frac{5}{s^3}$$

$$E(s) = \frac{5}{s^3} \cdot \frac{s^2(s+4) \cdot \dots (s+12)}{s^2(s+4) \cdot \dots (s+12) + K(s+1)(s+6)(s+8)}$$

~~$$E(s) = \lim_{s \rightarrow 0} \frac{5}{s^3} \cdot s$$~~

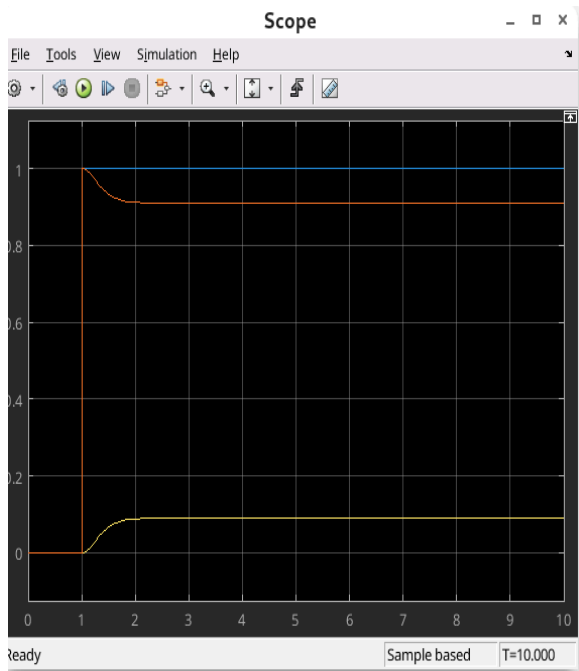
$$E(s) = \lim_{s \rightarrow 0} s \cdot E(s) = \frac{s \cdot 4 \cdot 7 \cdot 9 \cdot 12 \cdot 12}{0 + K \cdot 1 \cdot 6 \cdot 8}$$

$$E(s) = \frac{315}{K}$$

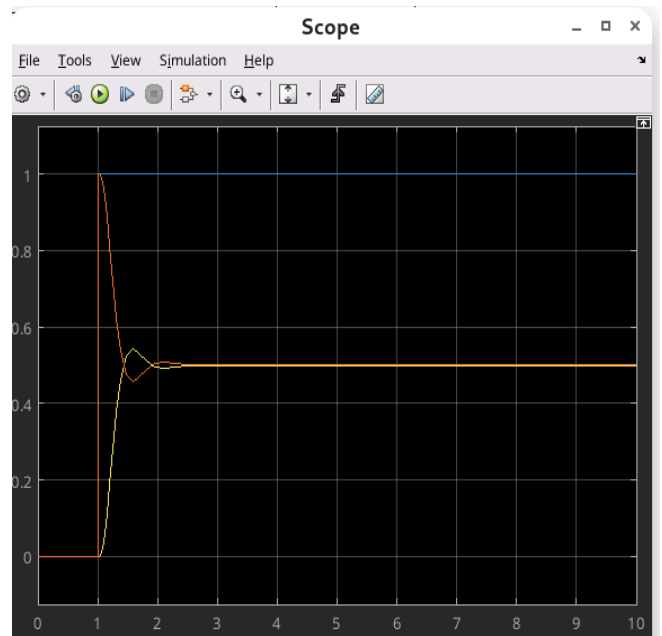
Graphs

a) Question-6

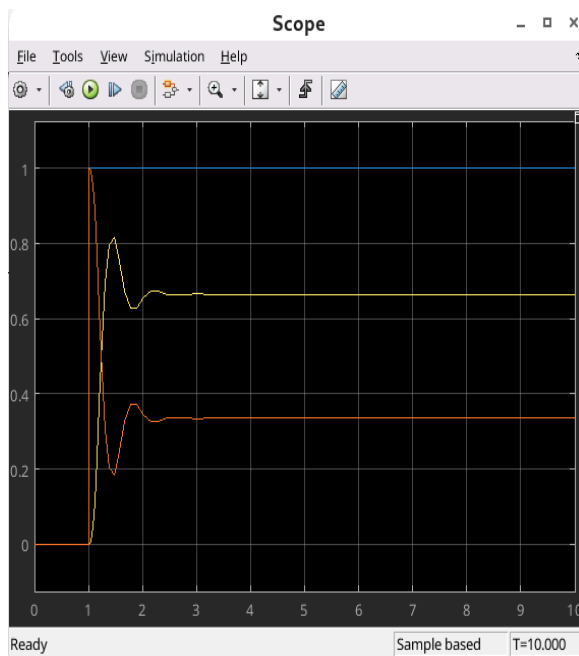
Step Input



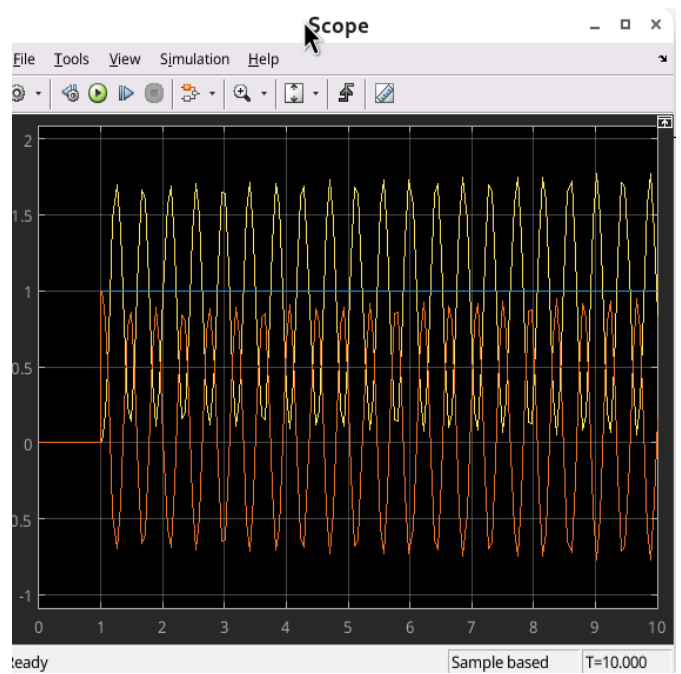
k=50



k=500



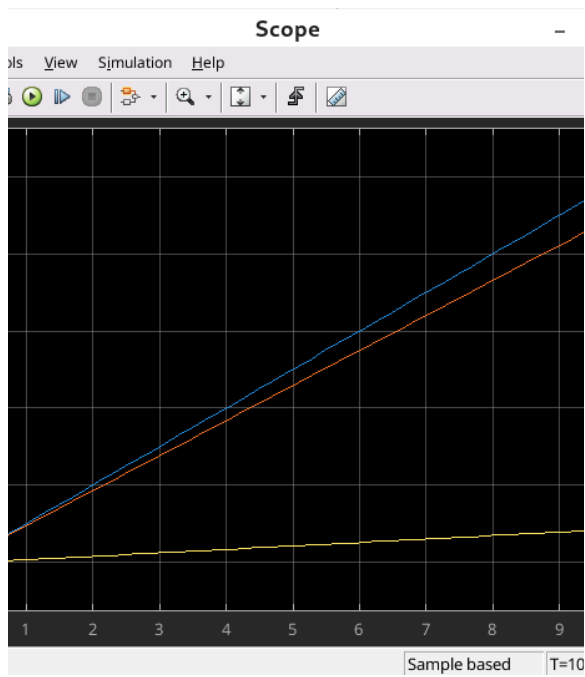
K=1000



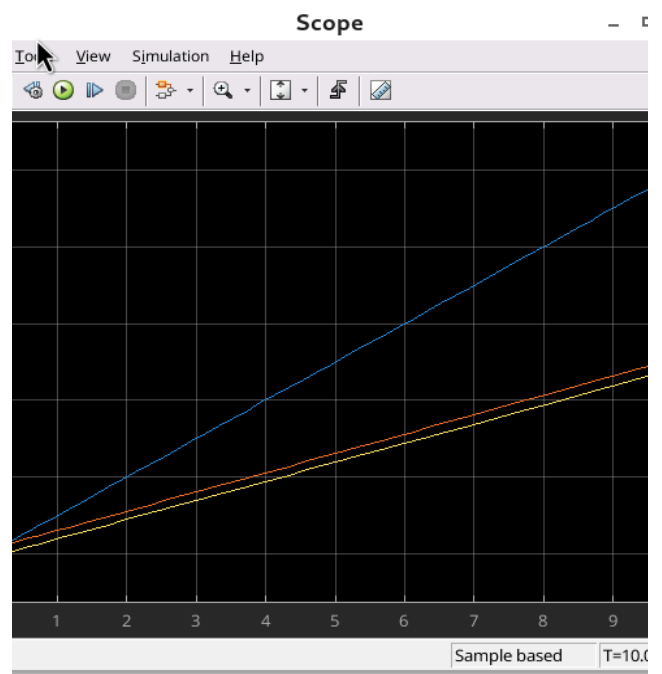
k=5000

a) Question-6

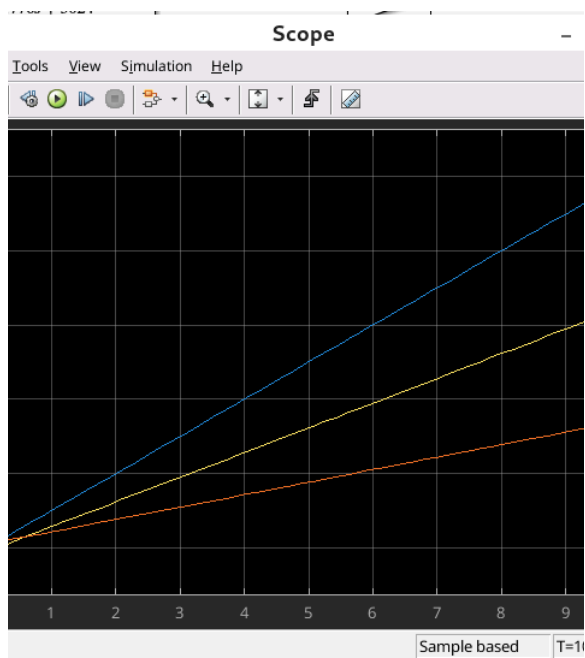
Ramp Input



k=50

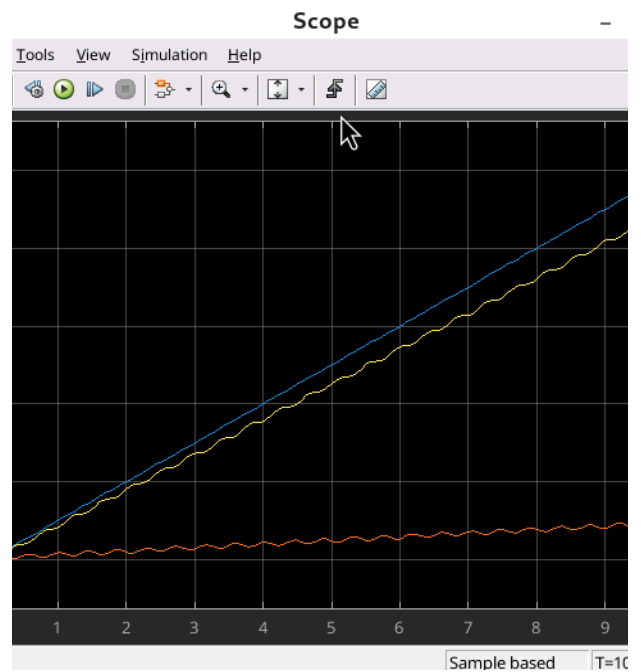


k=500



K=1000

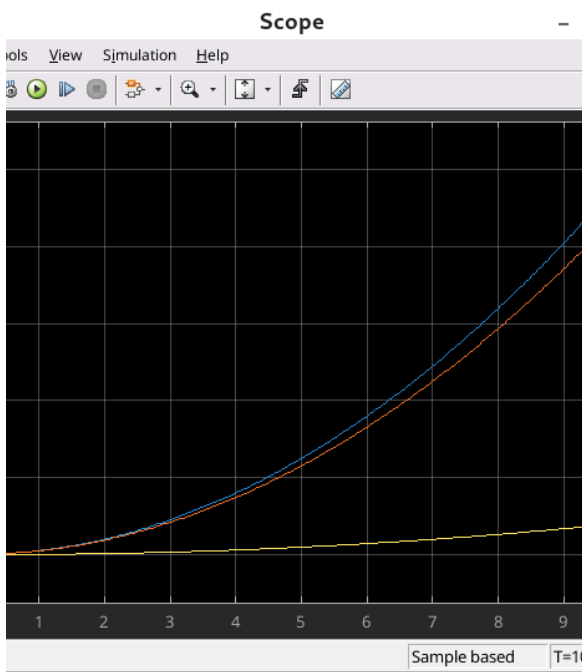
[OBJ]



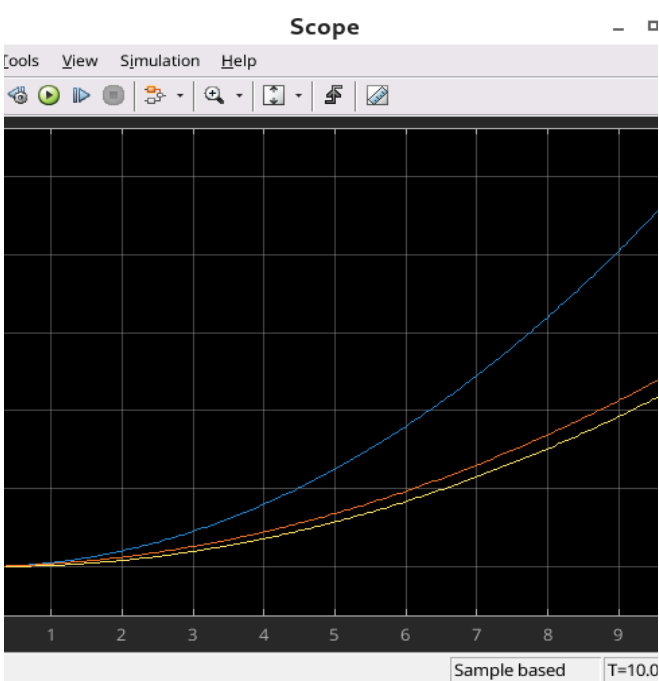
k=5000

a) Question-6

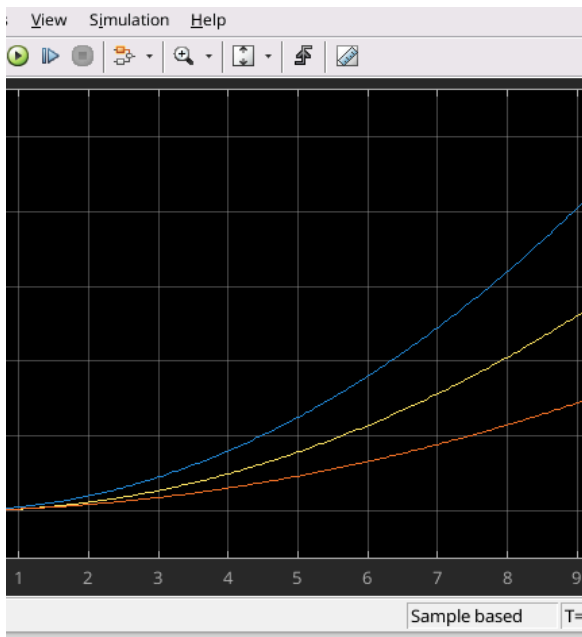
Polynomial Input



k=50

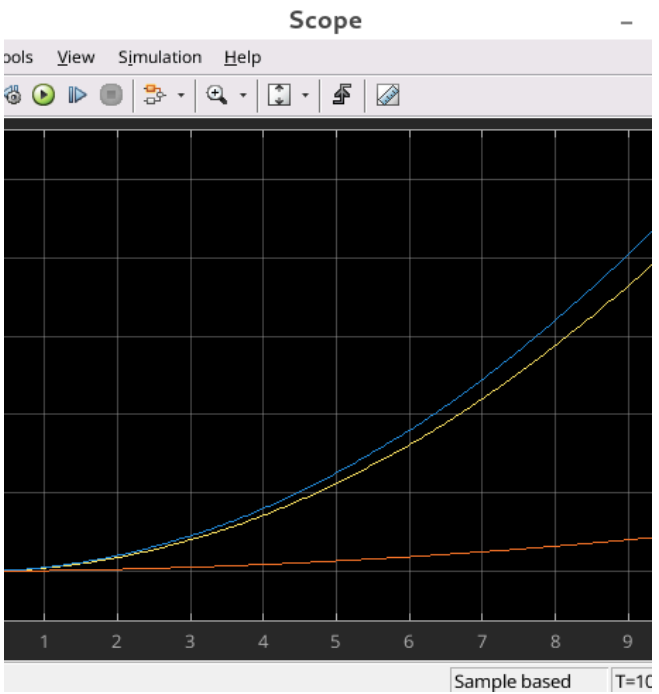


k=500



K=1000

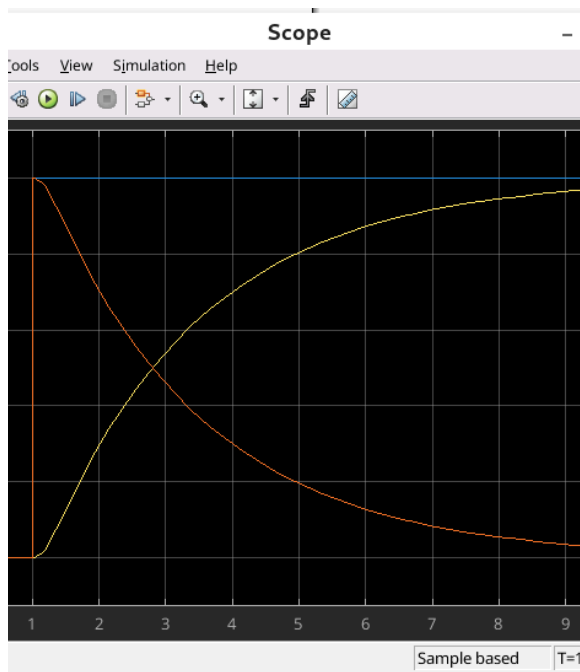
OBJ



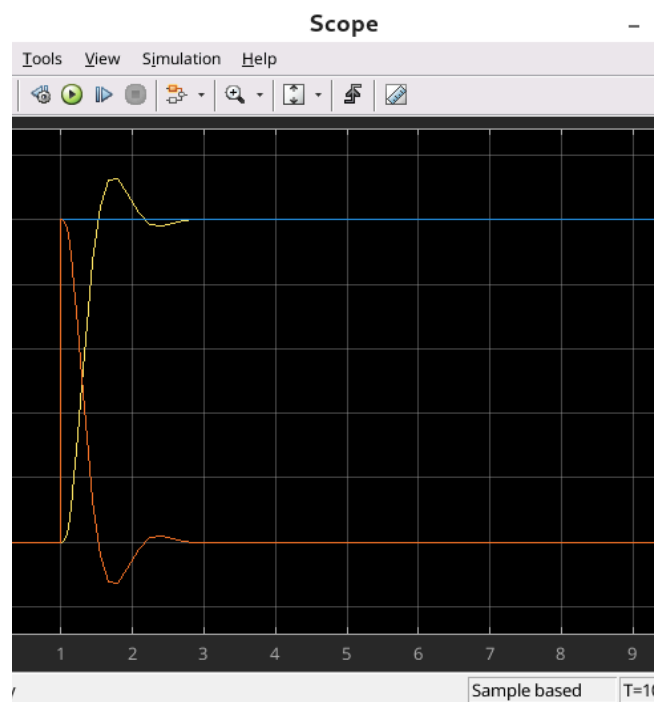
k=5000

b) Question-7

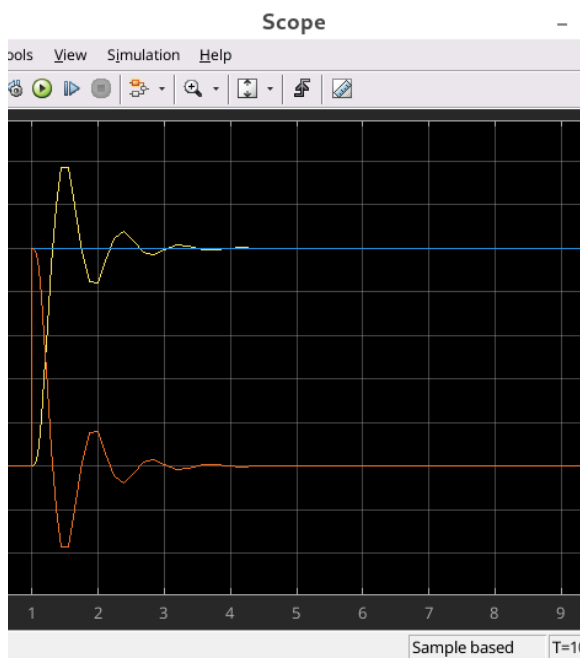
Step Input



$k=50$

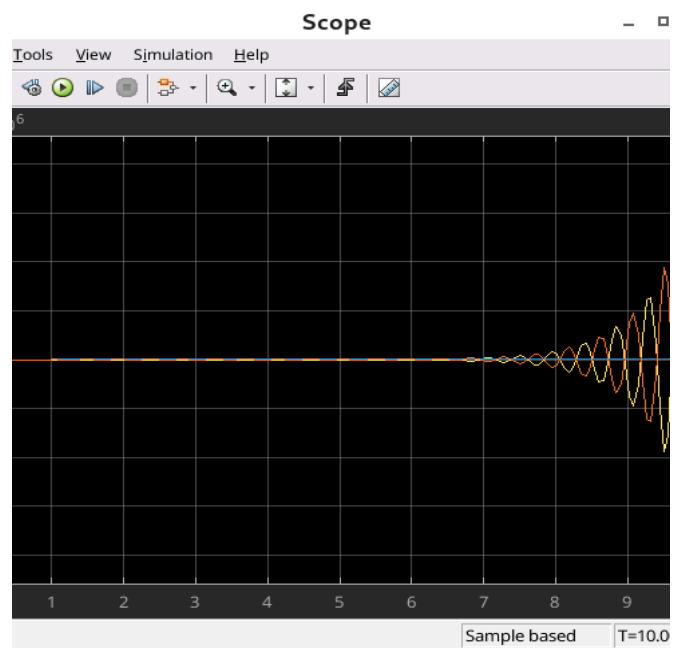


$k=500$



$K=1000$

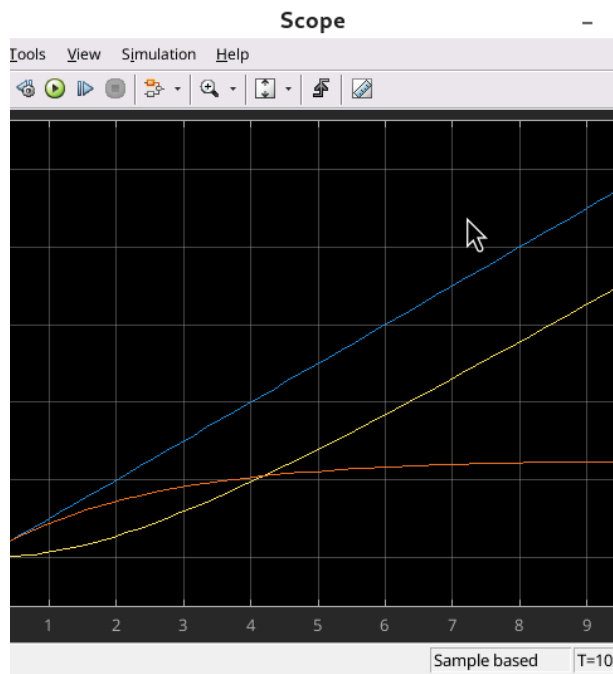
OBJ



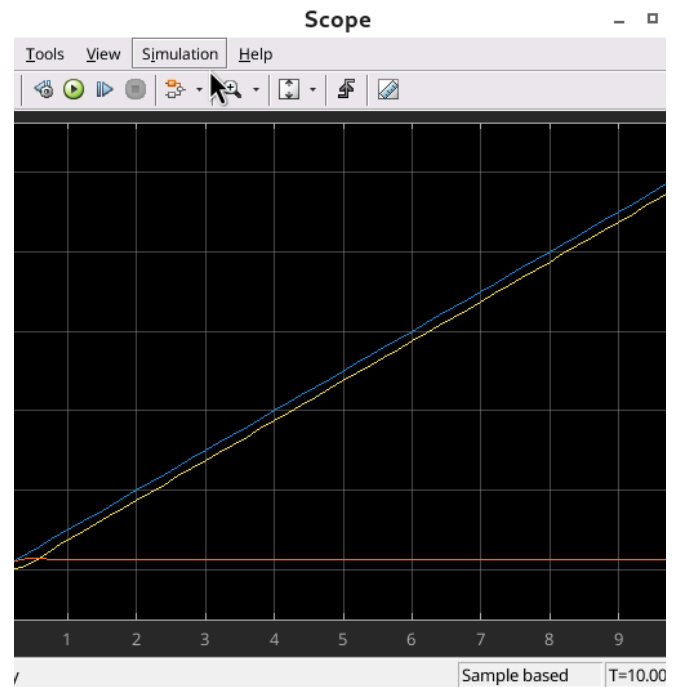
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b) Question-7

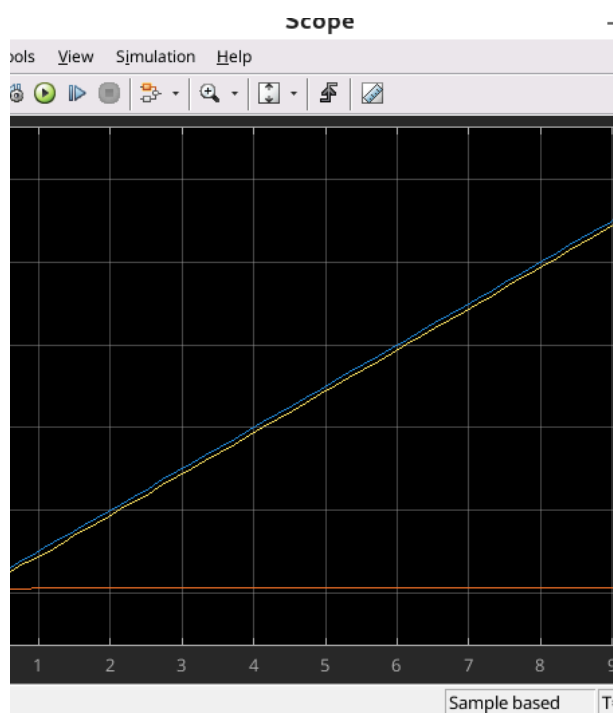
Ramp Input



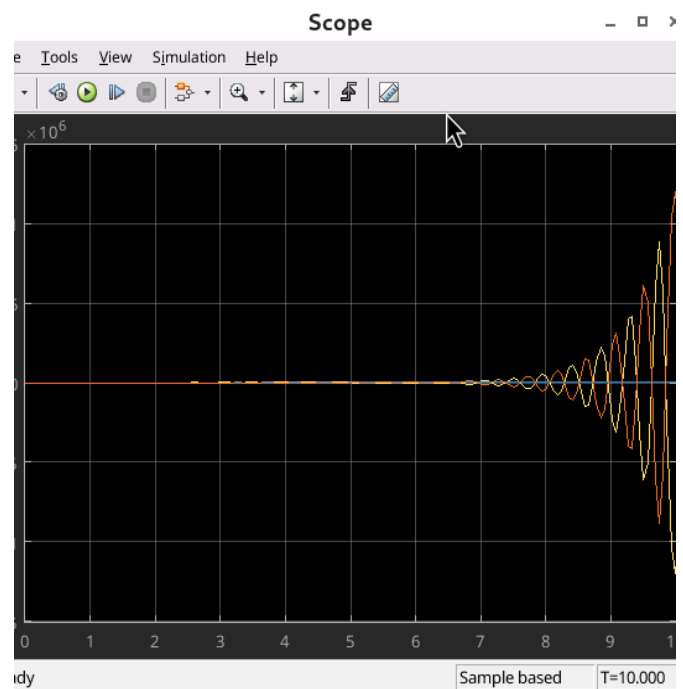
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$k=500$



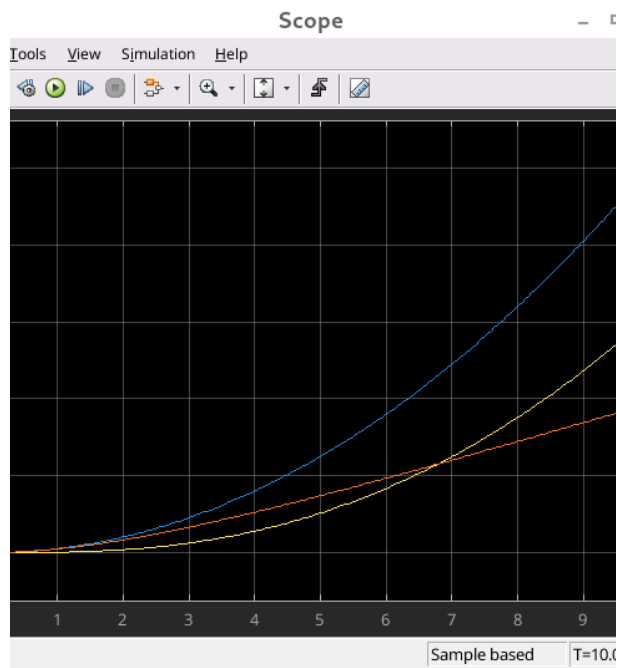
$K=1000$



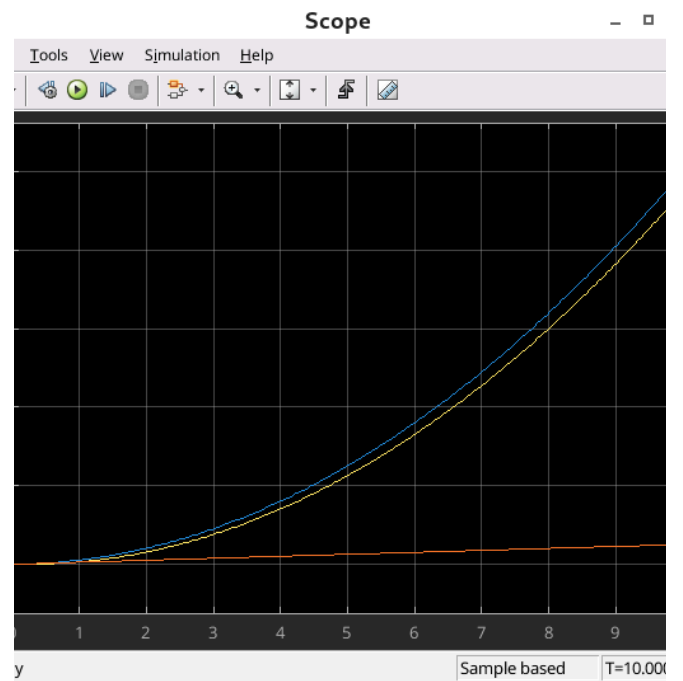
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b) Question-7

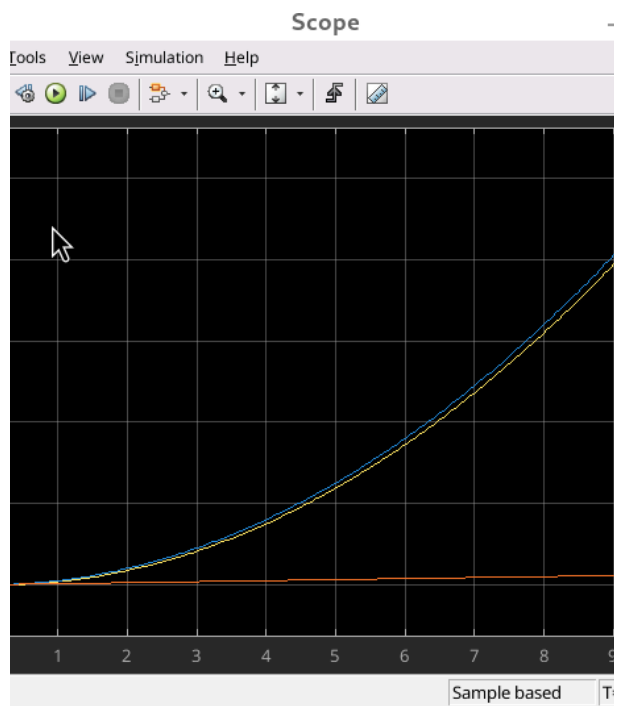
Ploynomial Input



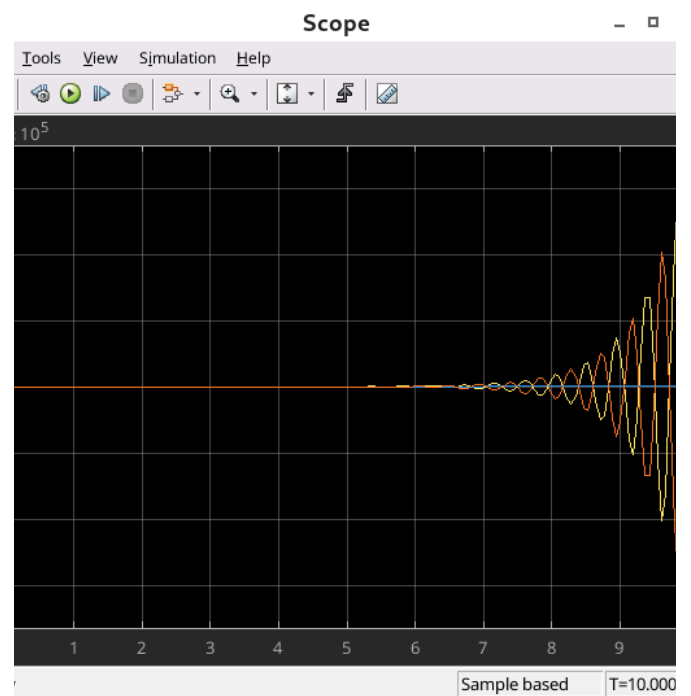
k=50



k=500



K=1000

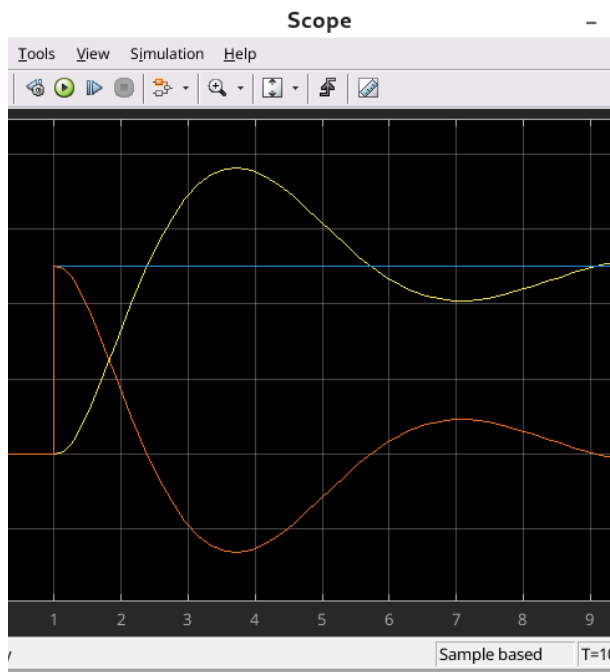


K=5000

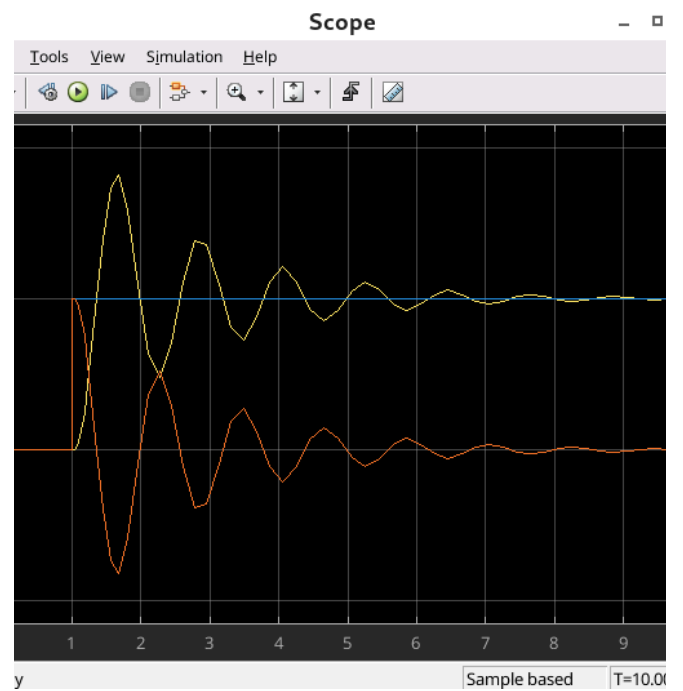
[OBJ]

c) Question-8

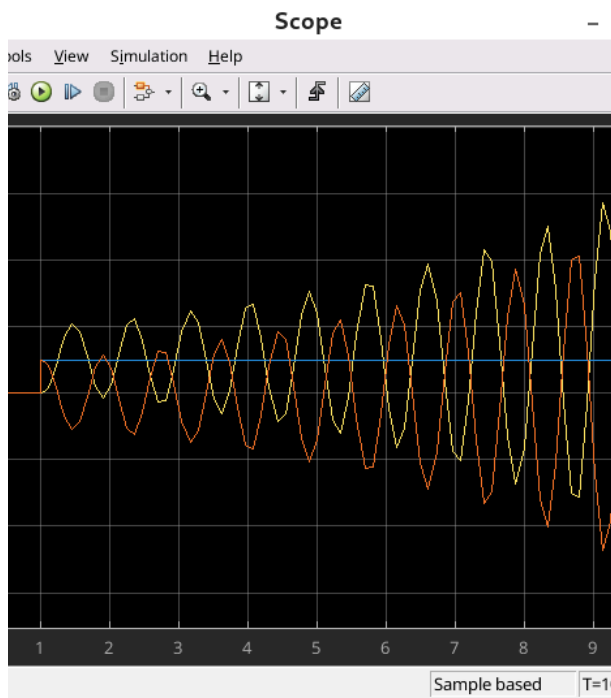
Step Input



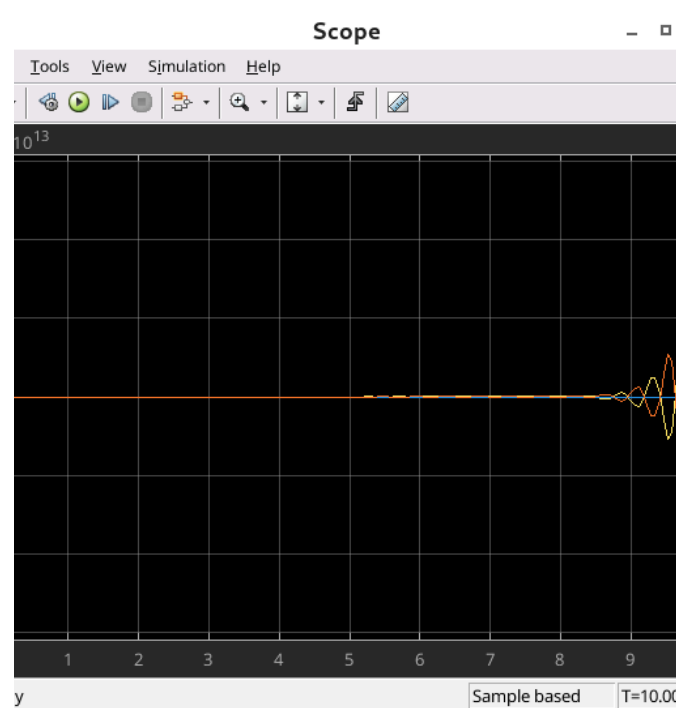
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$k=500$



$K=1000$

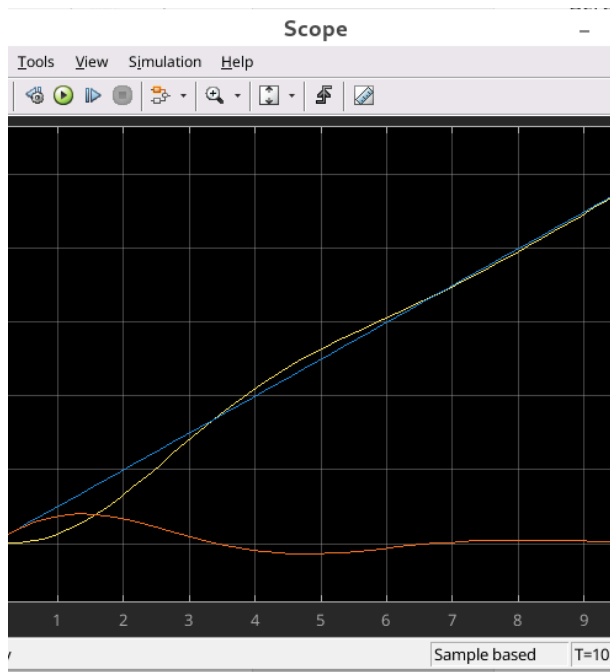


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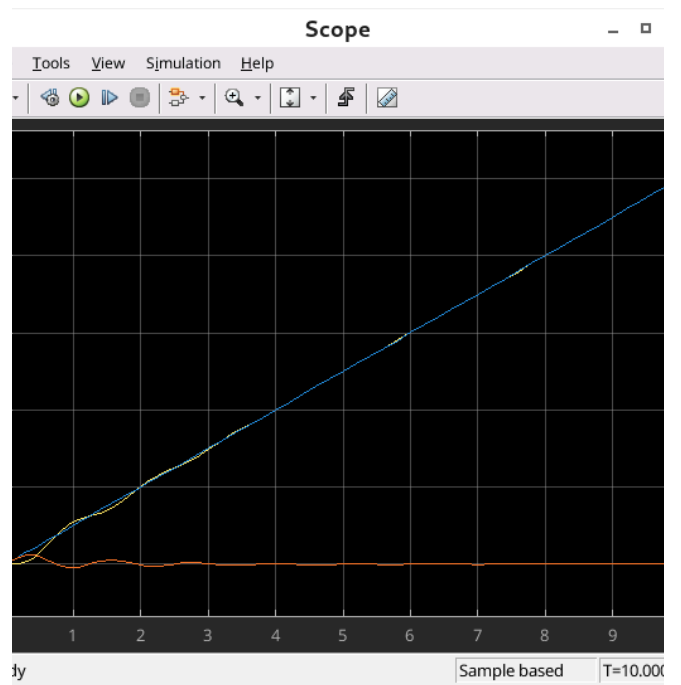
[OBJ]

c) Question-8

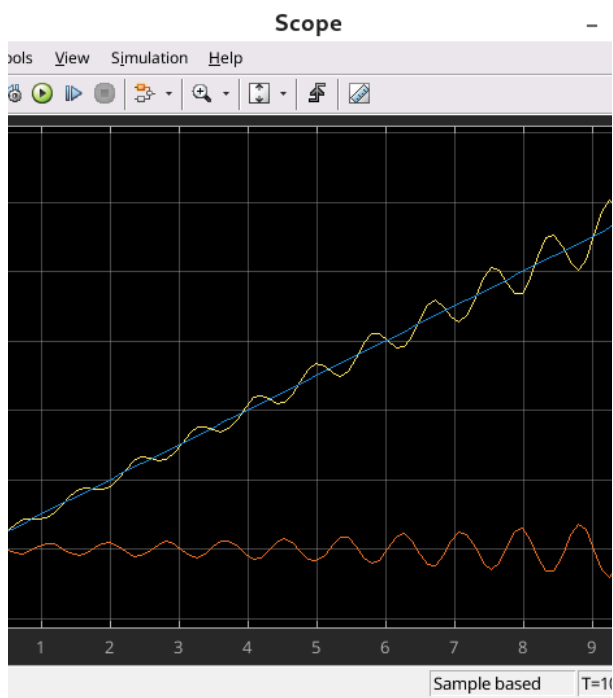
Ramp Input



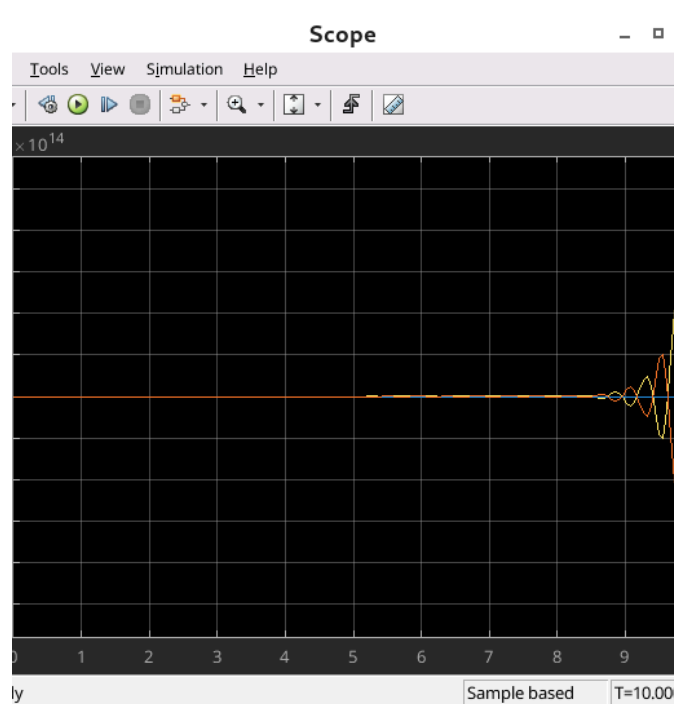
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$k=500$



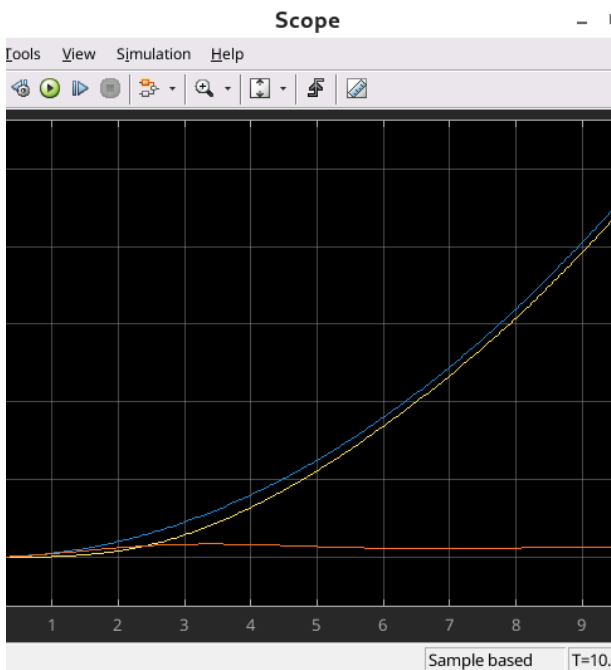
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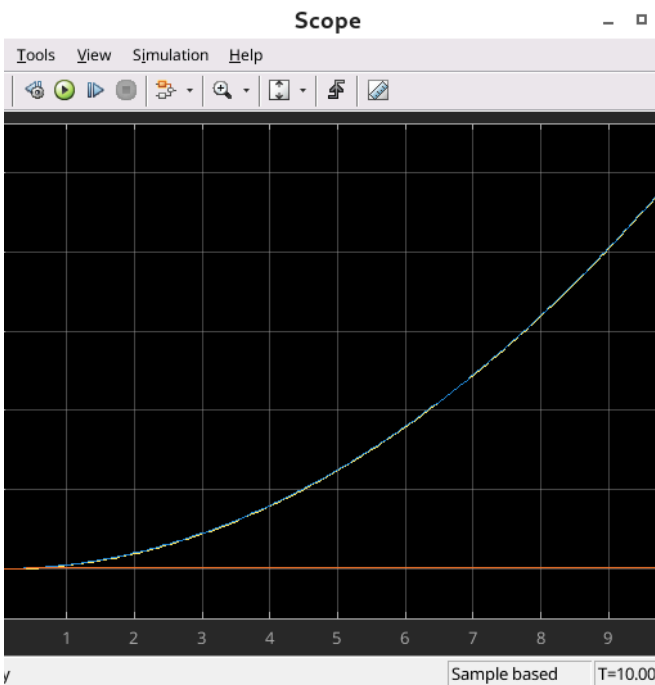
$K=5000$

c) Question-8

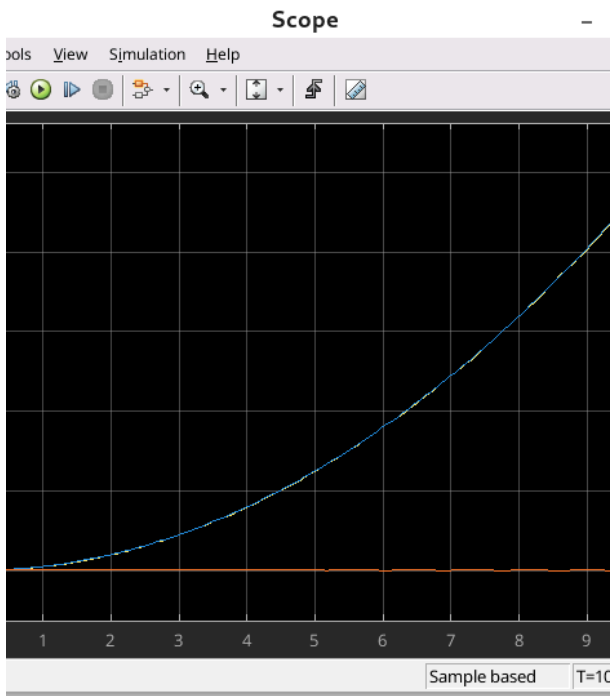
Polynomial Input



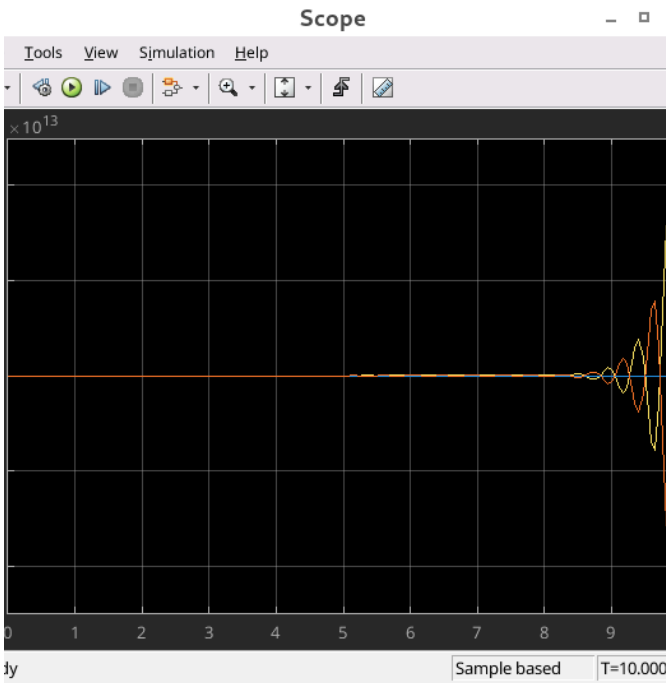
$k=50$



$k=500$



$K=1000$



$K=5000$