Lab 3

ECE 380 W21

Group 8

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Declaration of Authorship

We acknowledge and promise that:

a) We are the sole authors of this lab report and associated simulation files/code.
b) This work represents our original work.
c) We have not shared detailed analysis or detailed design results, computer code, or Simulink diagrams with any other student.
d) We have not obtained or looked at lab reports from any other current or former student of ECE/SE 380, and we have not let any other student access any part of our lab work.
e) We have completely and unambiguously acknowledged and referenced all persons and aids used to help us with our work.

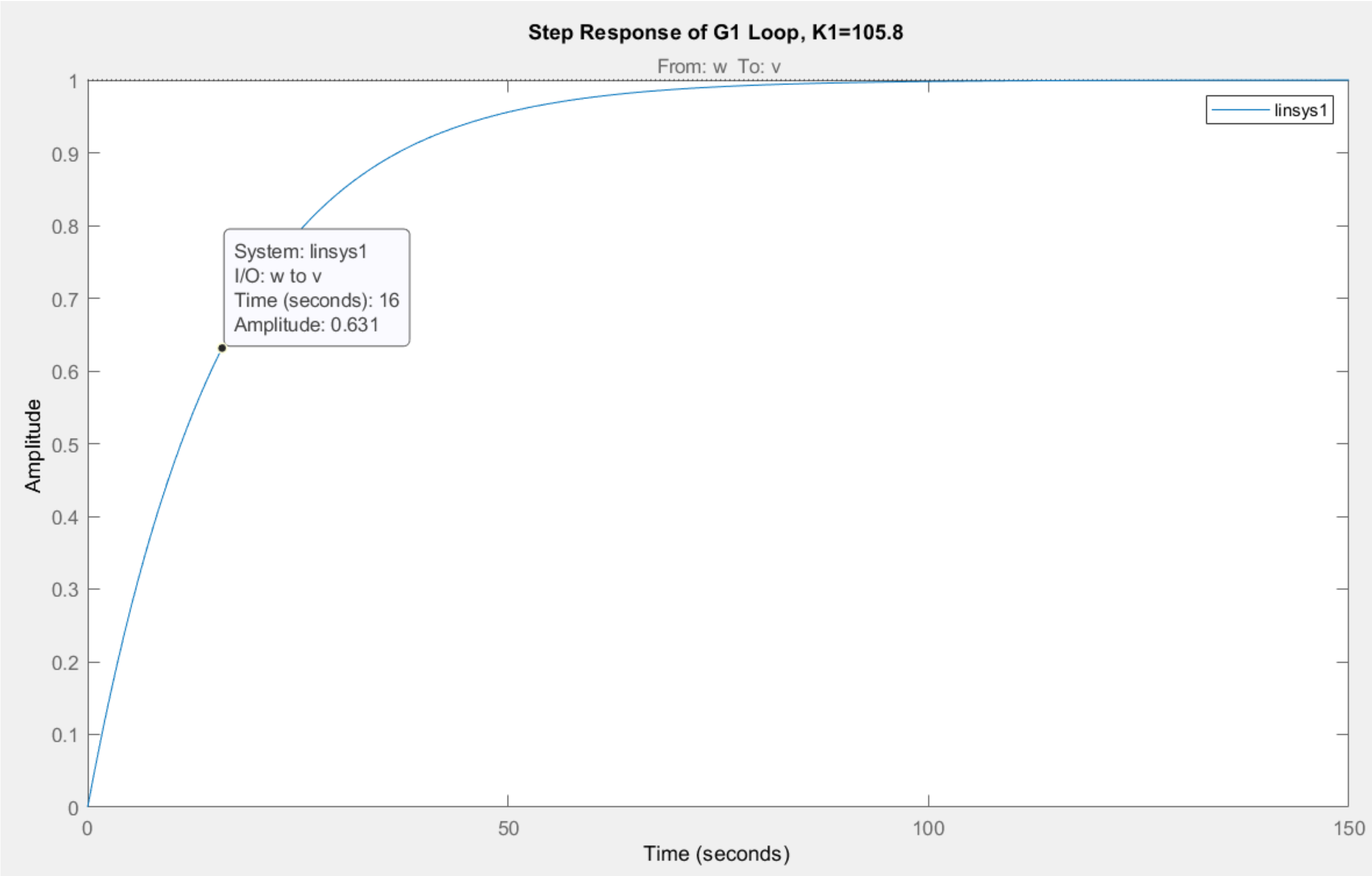
<u>Student1 Name and Signature:</u>

Arjun Bawa

<u>Student2 Name and Signature:</u>

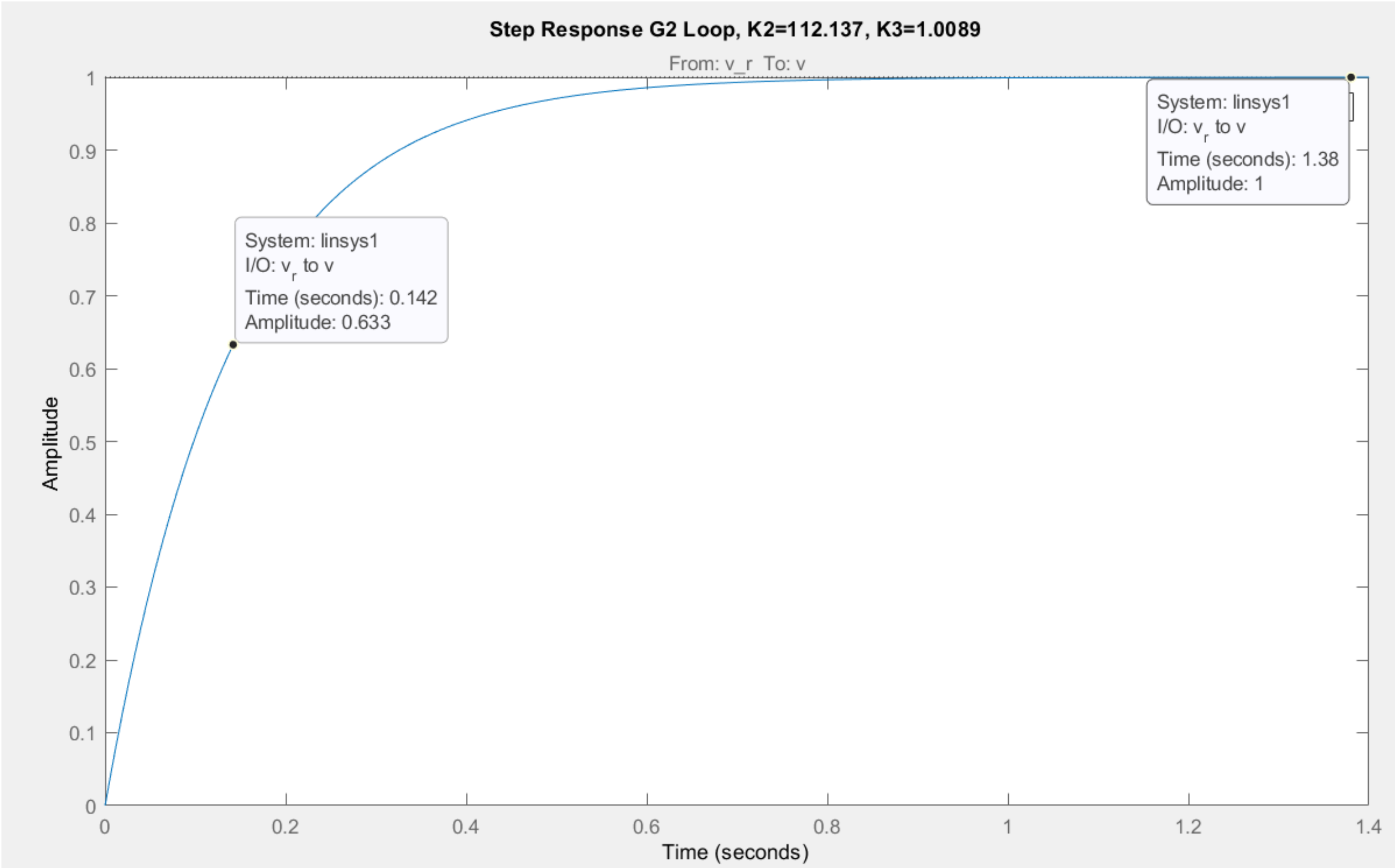
Andrew Tran

3.1 to 3.3



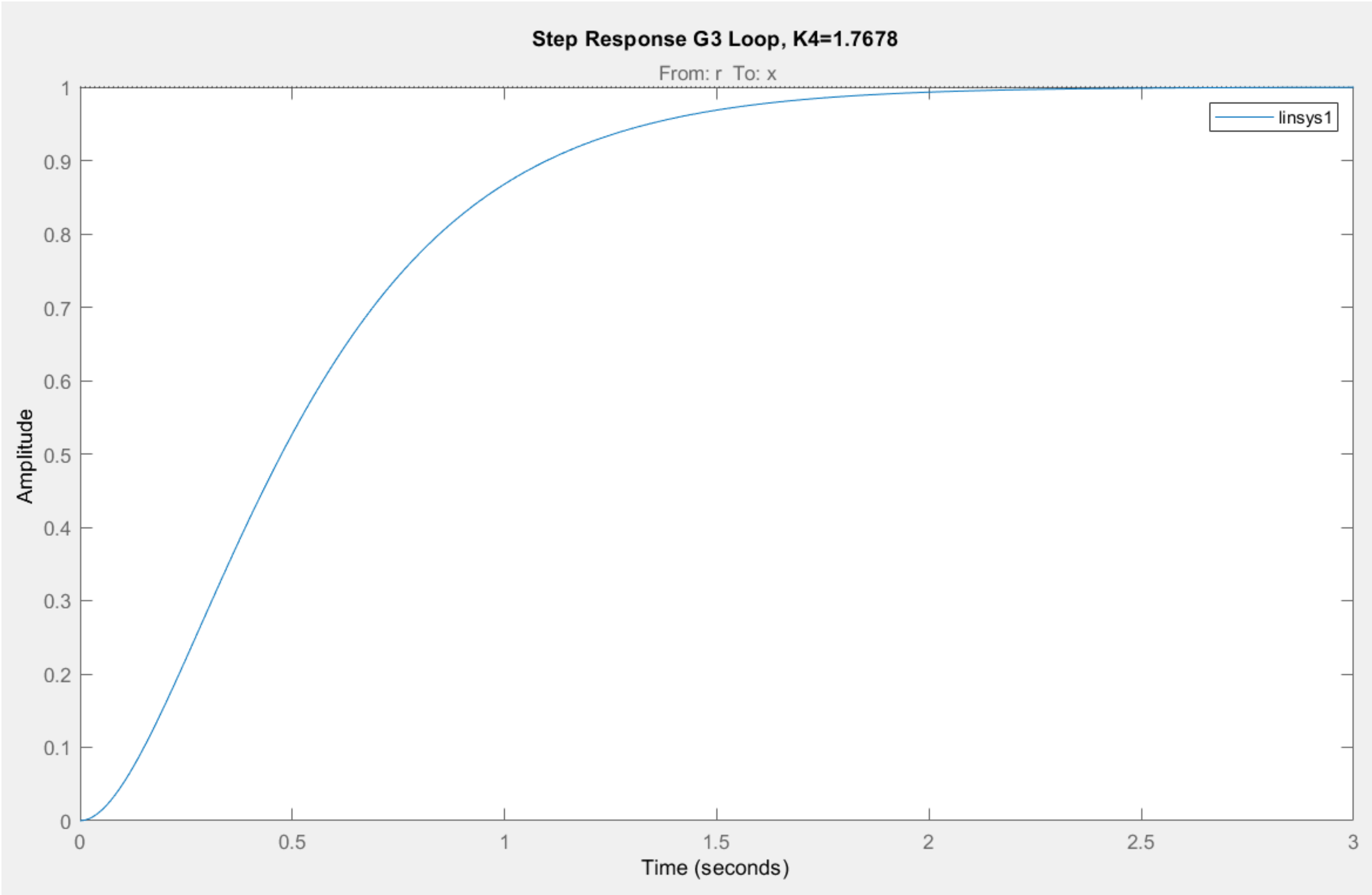
Time constant = 16s

3.4

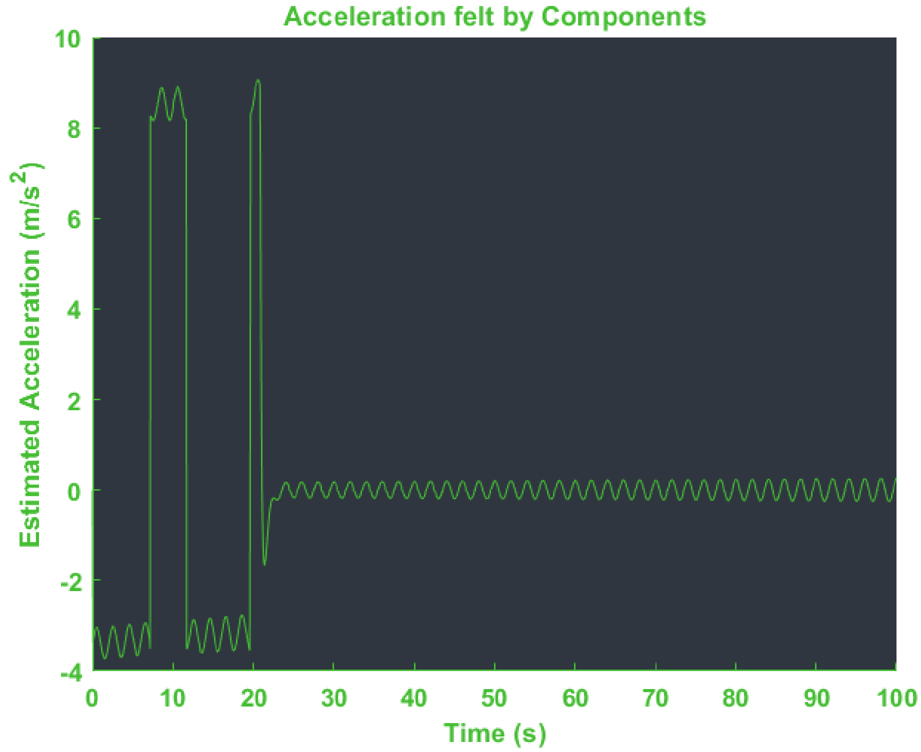


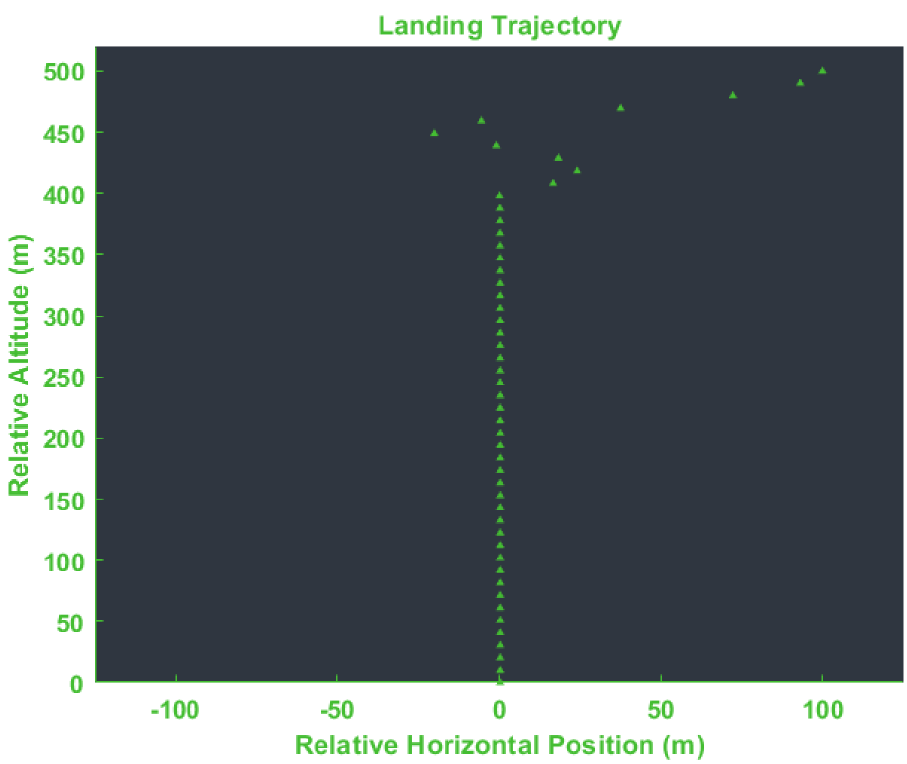
Step Response G2 Loop, K2=112.137, K3=1.0089
From: v_r To: v
System: linsys1
I/O: v_r to v
Time (seconds): 0.142
Amplitude: 0.633
System: linsys1
I/O: v_r to v
Time (seconds): 1.38
Amplitude: 1
Amplitude
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8
1
1.2
1.4

3.5

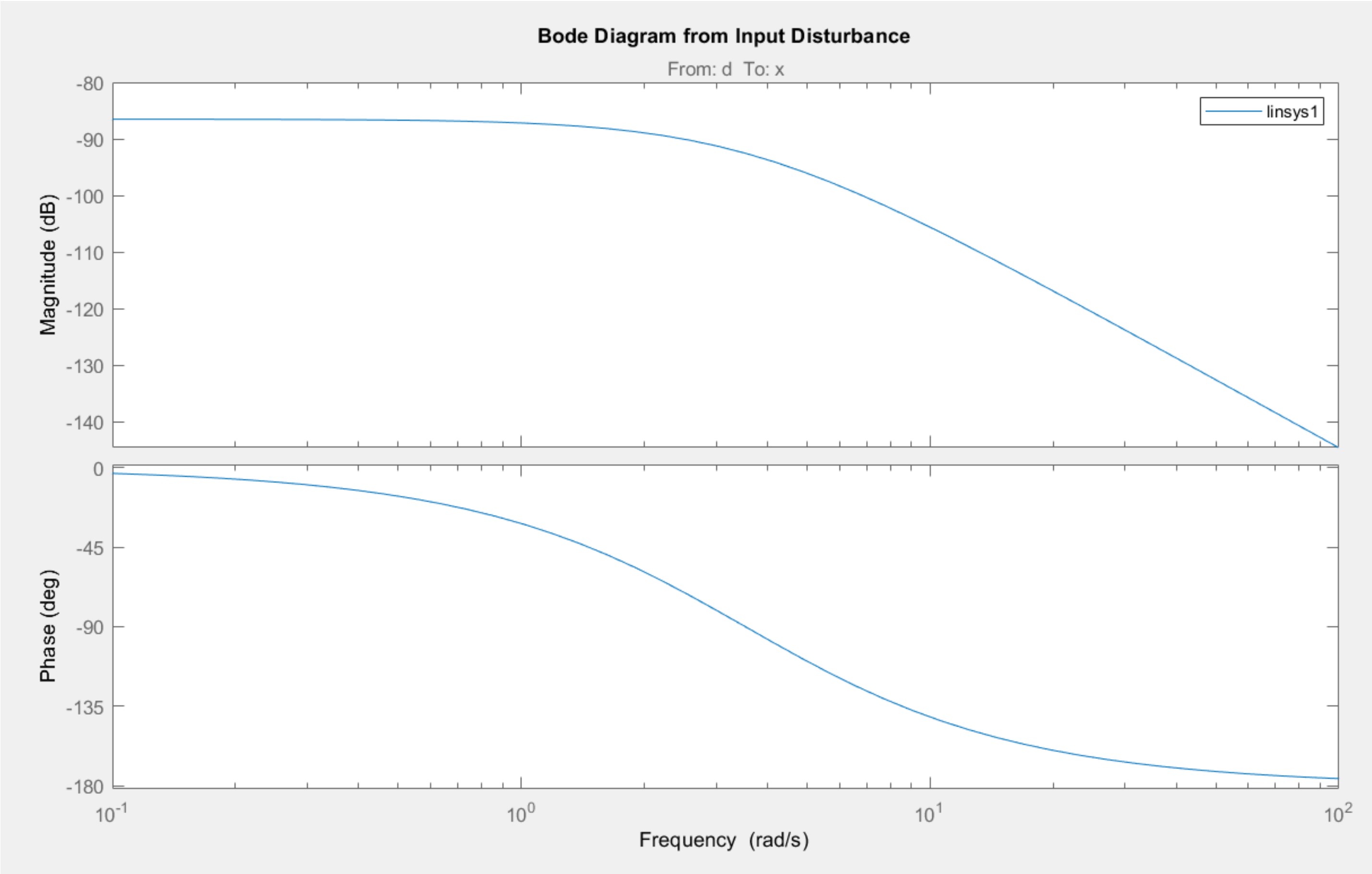

Step Response G3 Loop, K4=1.7678
From: r To: x
linsys1
Amplitude
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3

3.6


Acceleration felt by Components
Estimated Acceleration (m/s^2)
10
8
6
4
2
0
-2
-4
0
10
20
30
40
50
60
70
80
90
100
Time (s)


Landing Trajectory
Relative Altitude (m)
500
450
400
350
300
250
200
150
100
50
0
-100
-50
0
50
100
Relative Horizontal Position (m)

3.7


Bode Diagram from Input Disturbance
From: d To: x
linsys1
Magnitude (dB)
-80
-90
-100
-110
-120
-130
-140
Phase (deg)
0
-45
-90
-135
-180
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency (rad/s)

3.8

1

1) Derive transfer func. from $r(t)$ to $x(t)$

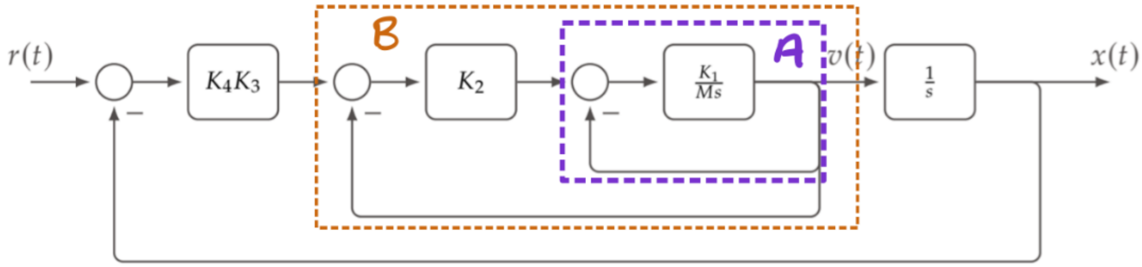


Figure 3.1: Entire closed-loop architecture for Lab 3.

$$A = \frac{k_1}{k_1 + Ms}$$

$$B = \frac{k_2 A}{1 + k_2 A} = \frac{k_1 k_2}{k_1 + Ms + k_2 k_1}$$

$$\Rightarrow \frac{X(s)}{R(s)} = \frac{\frac{1}{s} k_4 k_3 B}{1 + \frac{1}{s} k_4 k_3 B}$$

$$= \frac{\frac{1}{s} k_4 k_3 \frac{k_1 k_2}{k_1 + Ms + k_2 k_1}}{1 + \frac{1}{s} k_4 k_3 \frac{k_1 k_2}{k_1 + Ms + k_2 k_1}}$$

$$= \frac{k_1 k_2 k_3 k_4}{(k_1 + k_1 k_2 + Ms)s + k_1 k_2 k_3 k_4}$$

$$= \frac{k_1 k_2 k_3 k_4}{Ms^2 + (k_1 + k_1 k_2)s + k_1 k_2 k_3 k_4}$$

$$= \boxed{\frac{1}{M} \cdot \frac{k_1 k_2 k_3 k_4}{s^2 + \left(\frac{k_1 + k_1 k_2}{M}\right)s + \frac{k_1 k_2 k_3 k_4}{M}}}$$

2) Write T.F. in standard 2^{nd} order form. Find DC Gain $\hat{K}$, ω_n and ζ

$$\frac{X(s)}{R(s)} = \frac{\frac{1}{M}K_1K_2K_3K_4}{s^2 + \left(\frac{K_1 + K_1K_2}{M}\right)s + \frac{K_1K_2K_3K_4}{M}}$$

let $H(s) = \frac{X(s)}{R(s)} \Rightarrow \boxed{\hat{K} = |H(0)| = 1}$

$$\omega_n^2 = \frac{K_1K_2K_3K_4}{M} \Rightarrow \boxed{\omega_n = \sqrt{\frac{K_1K_2K_3K_4}{M}}}$$

$$\zeta = \frac{K_1 + K_1K_2}{2M\omega_n} = \frac{\sqrt{M}(K_1 + K_1K_2)}{2M\sqrt{K_1K_2K_3K_4}}$$

$$= \boxed{\frac{K_1 + K_1K_2}{2\sqrt{MK_1K_2K_3K_4}}}$$

3) Identify the two gains that affect $T_{2\%}$

$$T_{2\%} \approx \frac{4}{\zeta\omega_n} = \frac{4}{\frac{K_1 + K_1K_2}{2\sqrt{MK_1K_2K_3K_4}} \cdot \sqrt{\frac{K_1K_2K_3K_4}{M}}}$$

$$= \frac{4 \cdot 2 \cdot \sqrt{M}\sqrt{MK_4K_3K_2K_1}}{(K_1 + K_1K_2)\sqrt{K_4K_3K_2K_1}} = \boxed{\frac{8M}{K_1 + K_1K_2}}$$

$\Rightarrow K_1$ and K_2 affect $T_{2\%}$

4) Determine a gain that can be changed to reduce %OS w/out affecting $T_{2\%}$

$$\ln(O.S.) = \frac{-\zeta\pi}{\sqrt{1-\zeta^2}} \Rightarrow \ln\left(\frac{1}{O.S.}\right) = \frac{\zeta\pi}{\sqrt{1-\zeta^2}}$$

$$\Rightarrow \ln\left(\frac{1}{O.S.}\right) = \frac{\dfrac{(k_1+k_1k_2)\pi}{2\sqrt{Mk_1k_2k_3k_4}}}{\sqrt{1-\dfrac{(k_1+k_1k_2)^2}{4Mk_1k_2k_3k_4}}}$$

$$= \frac{(k_1+k_1k_2)\pi}{\left(4Mk_1k_2k_3k_4-(k_1+k_1k_2)^2\right)^{1/2}}$$

$$\Rightarrow O.S. = \exp\left[\frac{-(k_1+k_1k_2)\pi}{\left(4Mk_1k_2k_3k_4-(k_1+k_1k_2)^2\right)^{1/2}}\right]$$

$a := k_1+k_1k_2 \qquad b := 4Mk_1k_2$

$$\Rightarrow O.S. = \exp\left(\frac{-a\pi}{\sqrt{bk_3k_4-a^2}}\right)$$

$\propto :=$ proportional , $\propto^{-1} :=$ inversely proportional

$$\Rightarrow O.S. \propto^{-1} \frac{a\pi}{\sqrt{bk_3k_4-a^2}} \propto^{-1} bk_3k_4-a^2$$

$$\Rightarrow k_3k_4 >> \frac{(k_1+k_1k_2)^2}{4Mk_1k_2} : O.S. \longrightarrow 1$$

Increasing the product of k_3 and k_4 increases O.S. $\Rightarrow$ decreasing k_3k_4 decreases O.S.