Control Engineering Assignment

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Requirement 1: The dynamic equations and the block diagram of the system

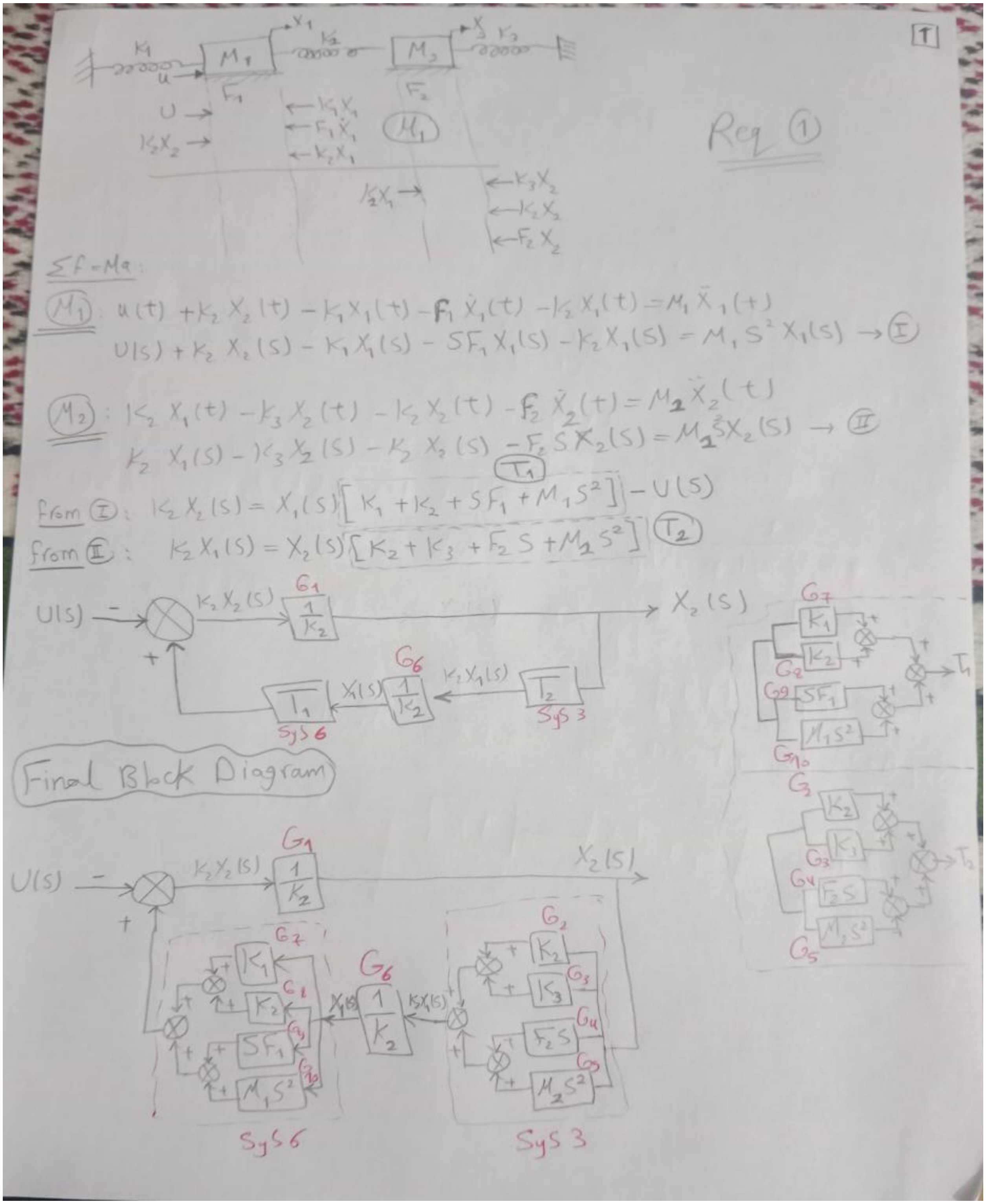


Figure 1: Handwritten analysis

Requirement 2:

$$X1\_over\_u = \frac{0.01 s^2 + 0.01 s + 0.0055}{s^4 + 2 s^3 + 2.1 s^2 + 1.1 s + 0.0525}$$

$$X2\_over\_u = \frac{0.005}{s^4 + 2 s^3 + 2.1 s^2 + 1.1 s + 0.0525}$$

Requirement 3:

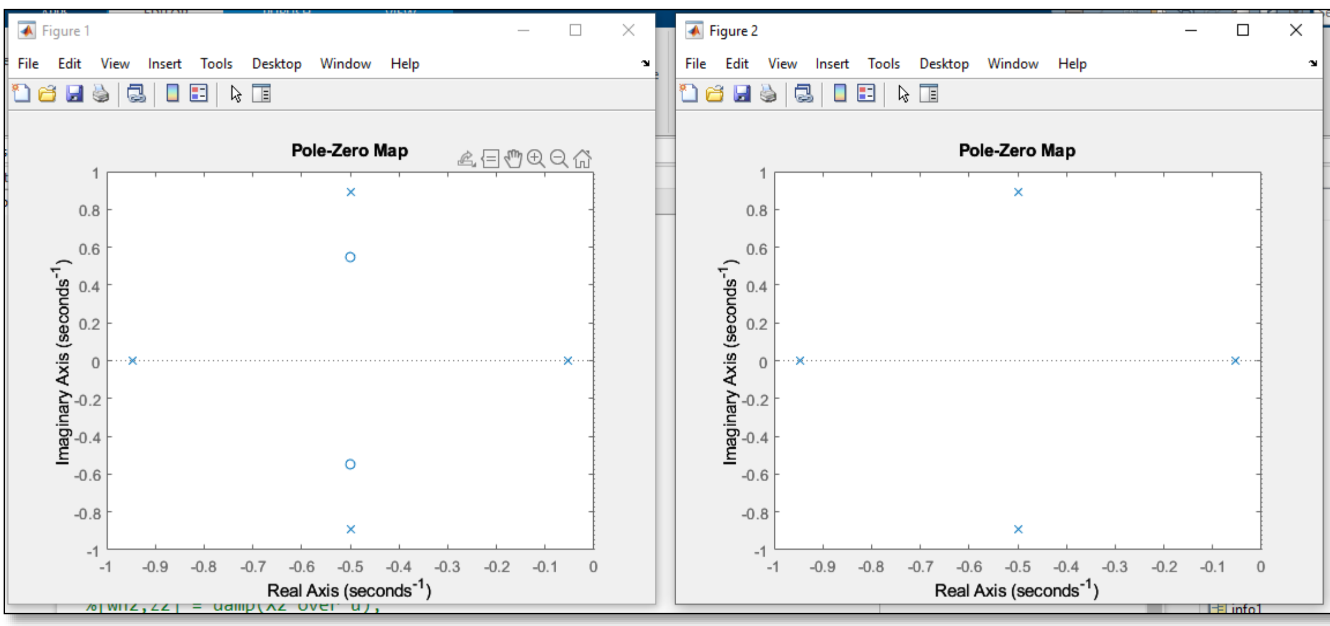


Figure 2: Poles of the two transfer functions X1, X2

As shown in Fig 2, For both of X1 and X2 all the poles are in the left half plane and no poles in the right half plane, so the system is stable.

Requirement 4:

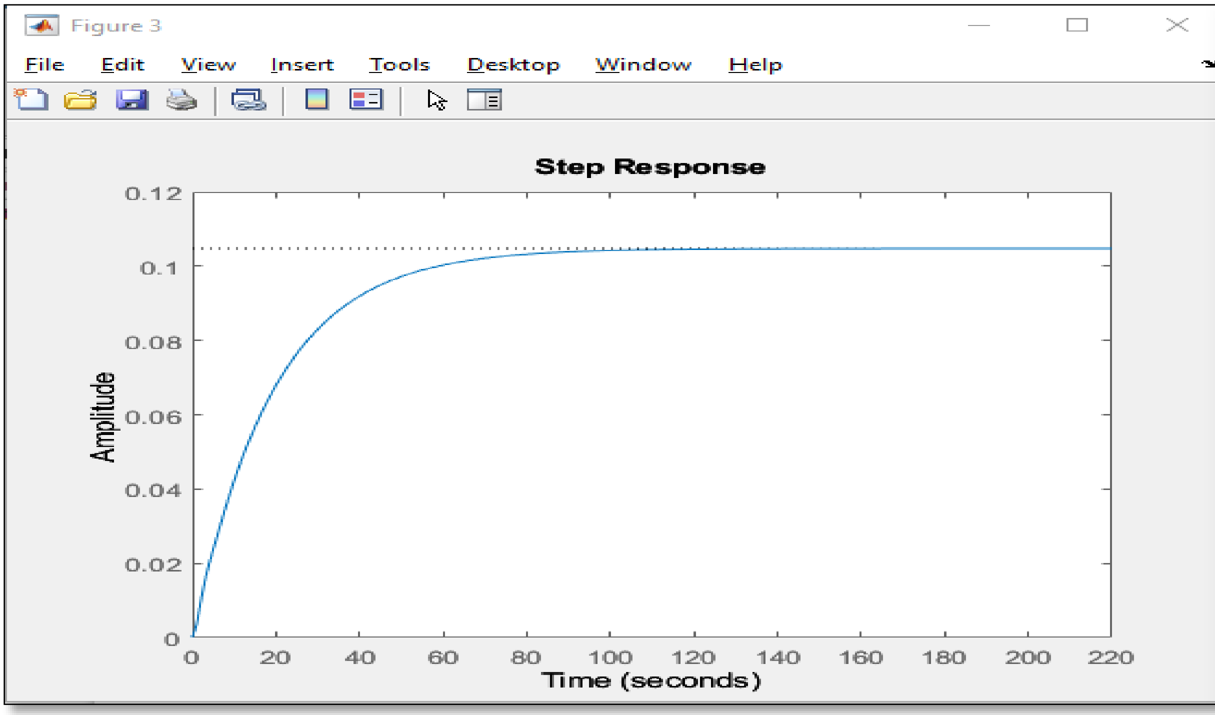


Figure 3: Response of X1 for input 1N

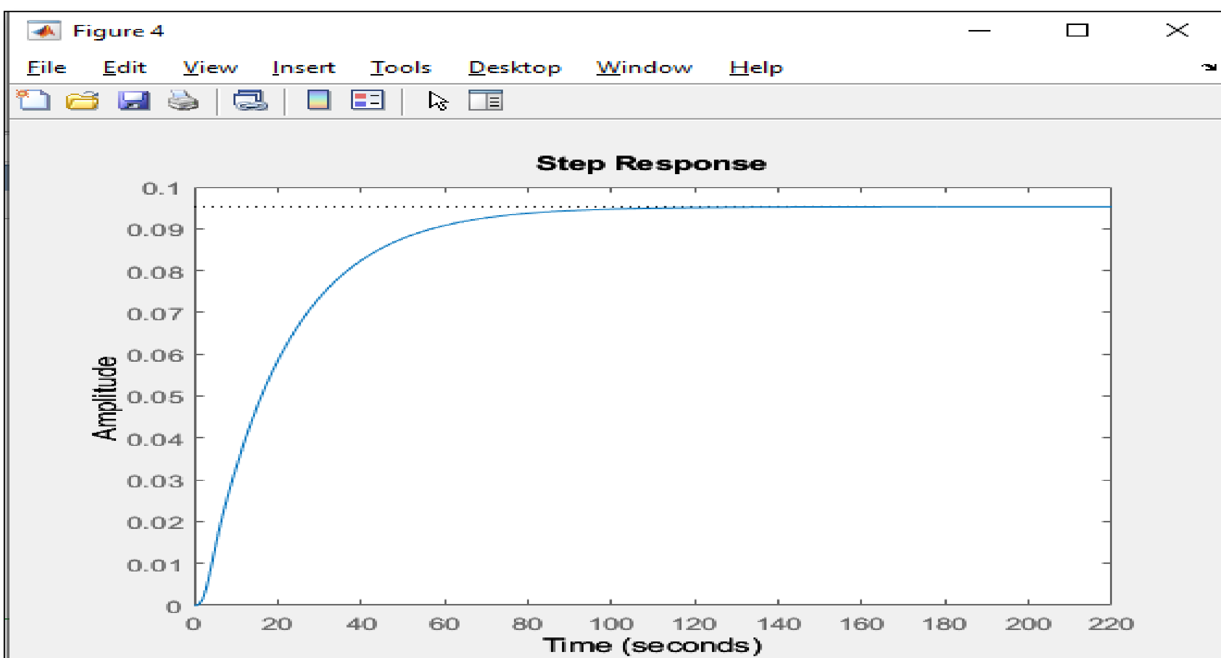


Figure 4: Response of X2 for input 1N

Steady State Values for X1	Steady State Values for X2
RiseTime: 41.7004 TransientTime: 74.3184 SettlingTime: 74.3184 SettlingMin: 0.0946 SettlingMax: 0.1048 Overshoot: 0 Undershoot: 0 Peak: 0.1048 PeakTime: 199.7833 **Steady State error X1:** 0.895	RiseTime: 41.5076 TransientTime: 76.1248 SettlingTime: 76.1248 SettlingMin: 0.0860 SettlingMax: 0.0952 Overshoot: 0 Undershoot: 0 Peak: 0.0952 PeakTime: 138.7141 **Steady State error X2:** 0.905

Requirement 5:

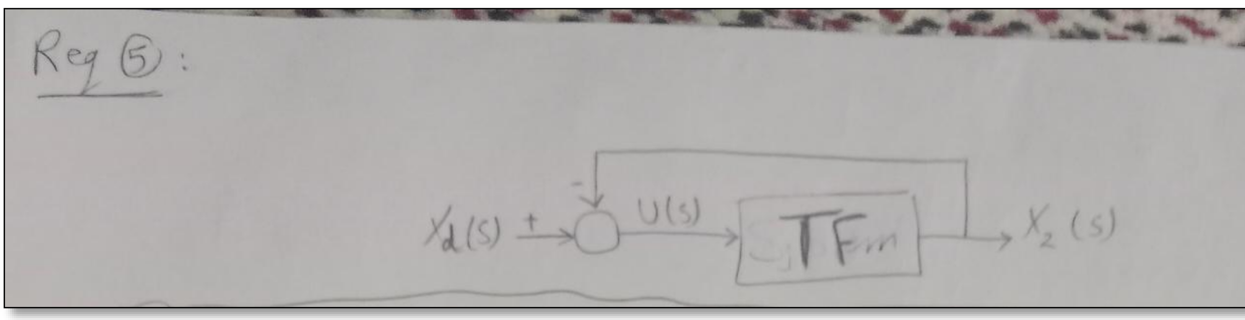


Figure 5: System modification such that Xd is input.

Requirement 6:

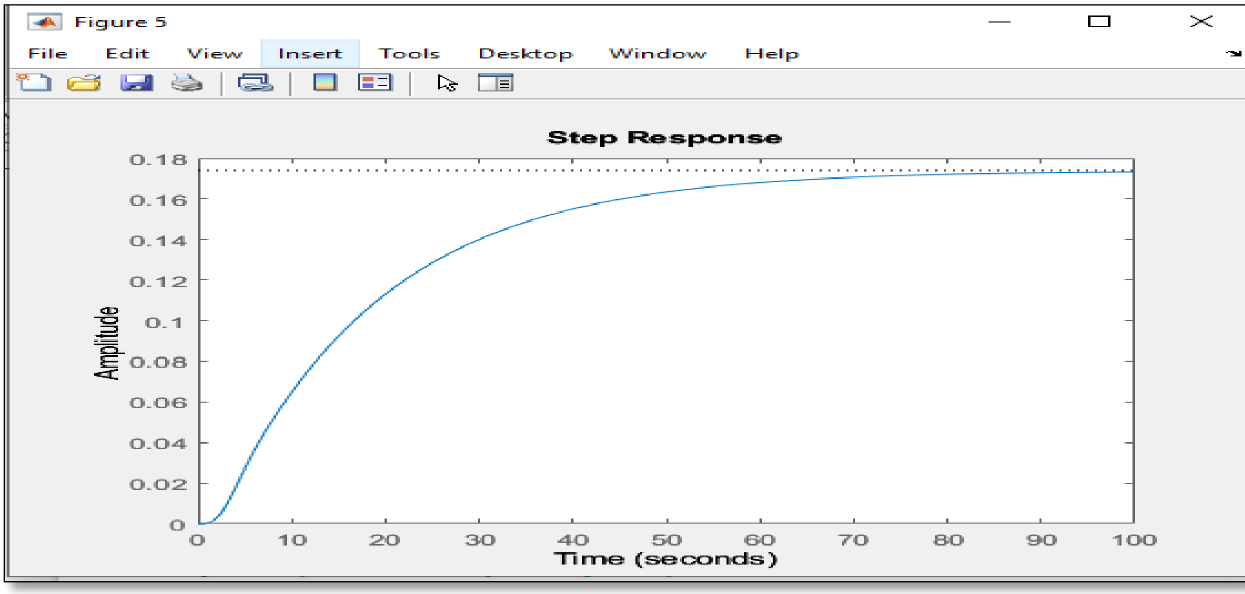


Figure 6: Response of the system for input Xd = 2

Requirement 7:

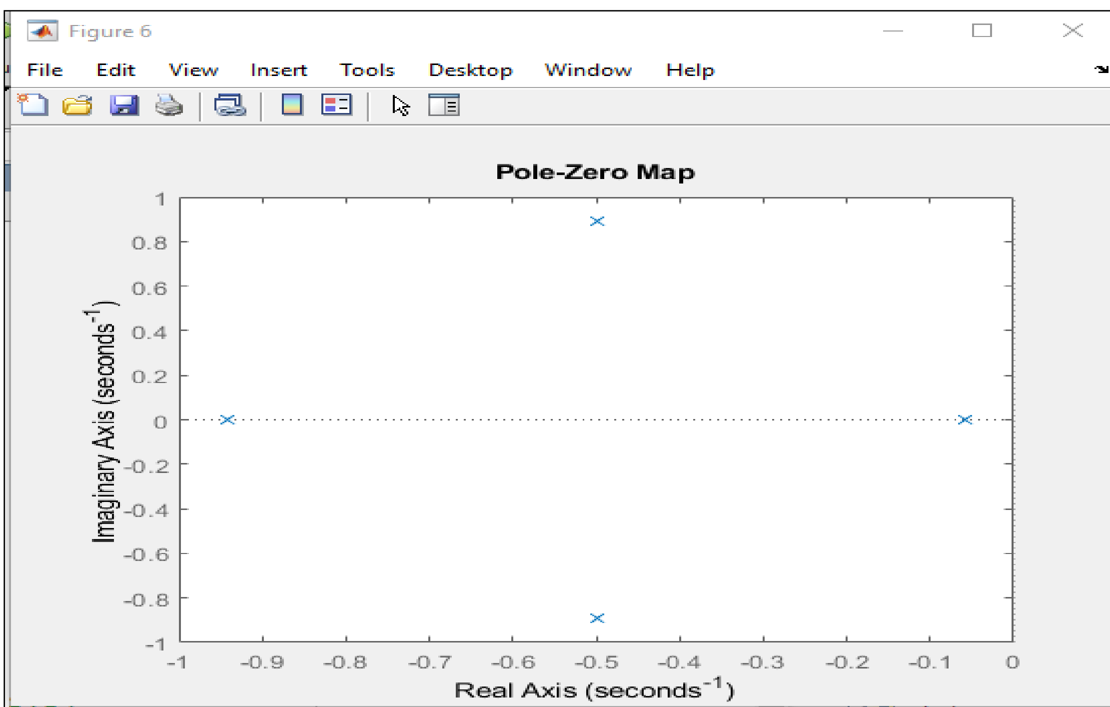


Figure 7: Poles of the system

As show in Fig 7, the system is stable as all the poles are in the negative side.

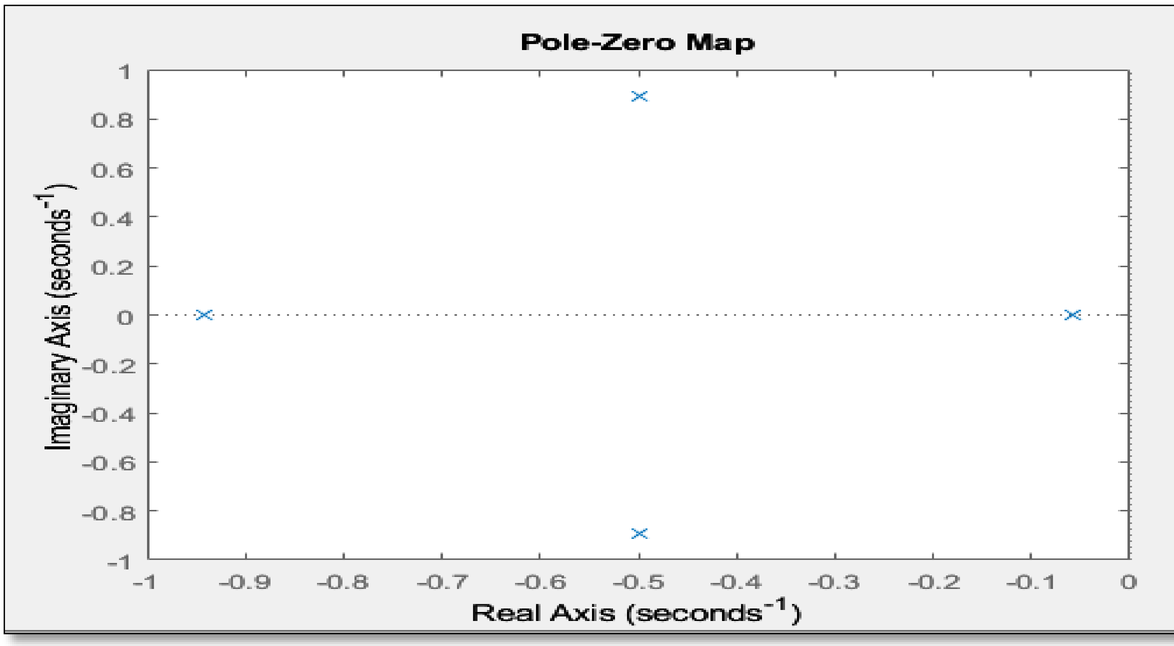
Steady State error: 1.827

- System Information:
- RiseTime: 37.4676
- TransientTime: 68.9668
- SettlingTime: 68.9668
- SettlingMin: 0.0784
- SettlingMax: 0.0869
- Overshoot: 0
- Undershoot: 0
- Peak: 0.0869
- PeakTime: 125.293

Requirement 8:

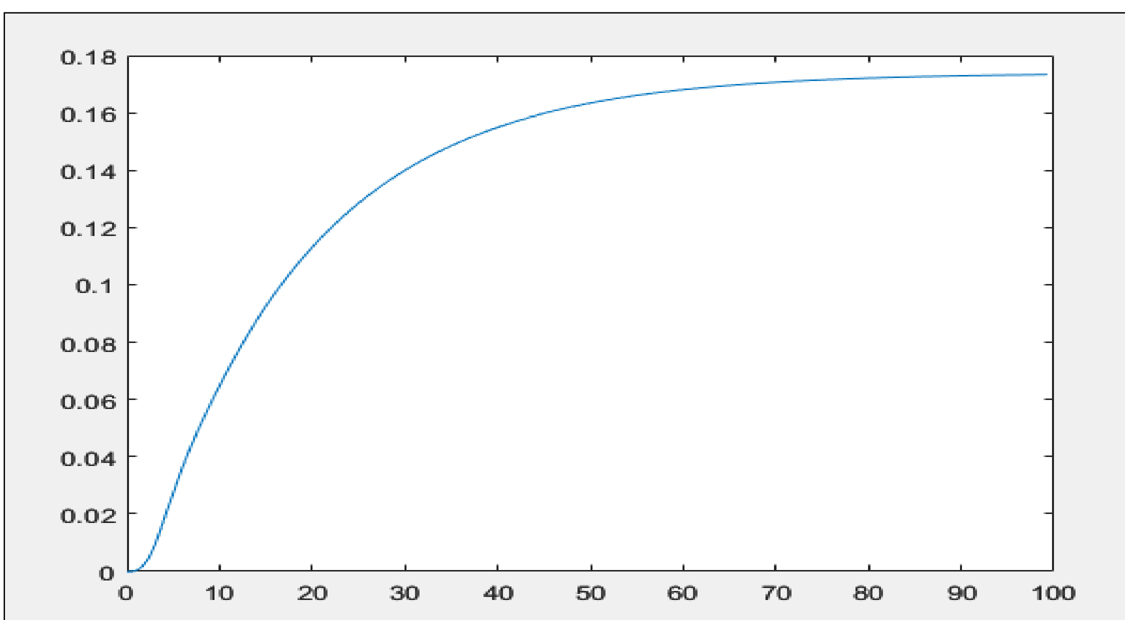
Kp value = 1

The stability of the system:

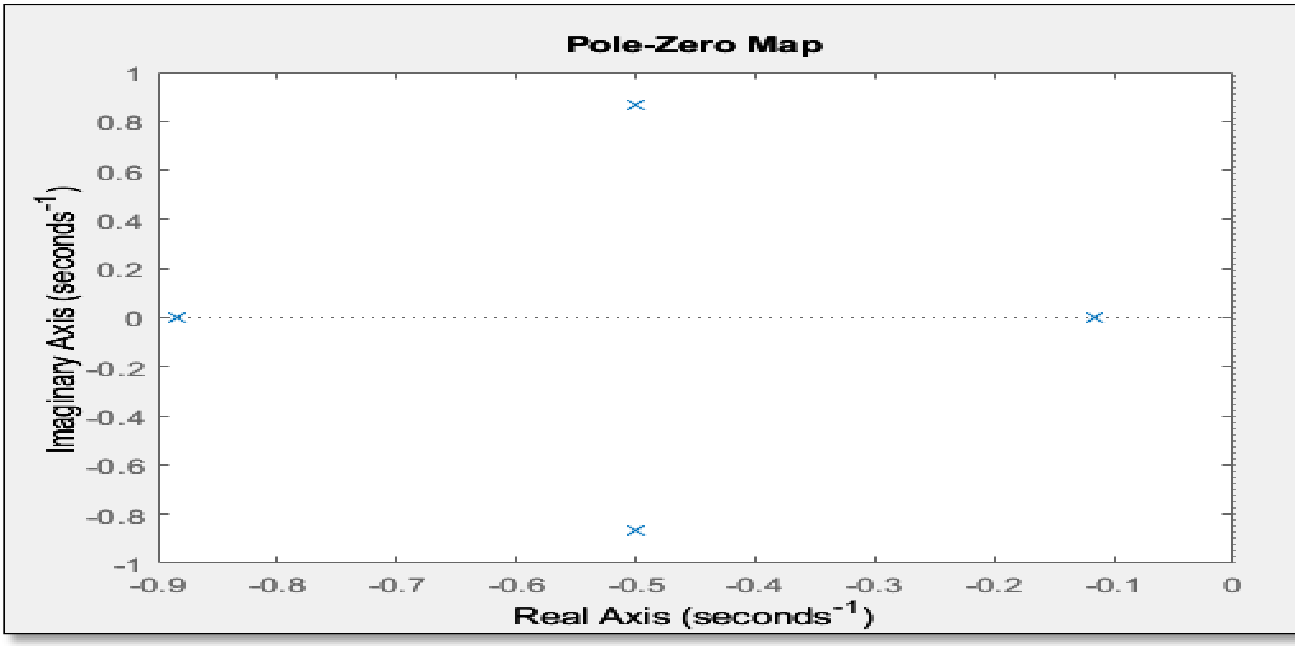


All poles are in left half plane, so the system is stable.

The response of the system:

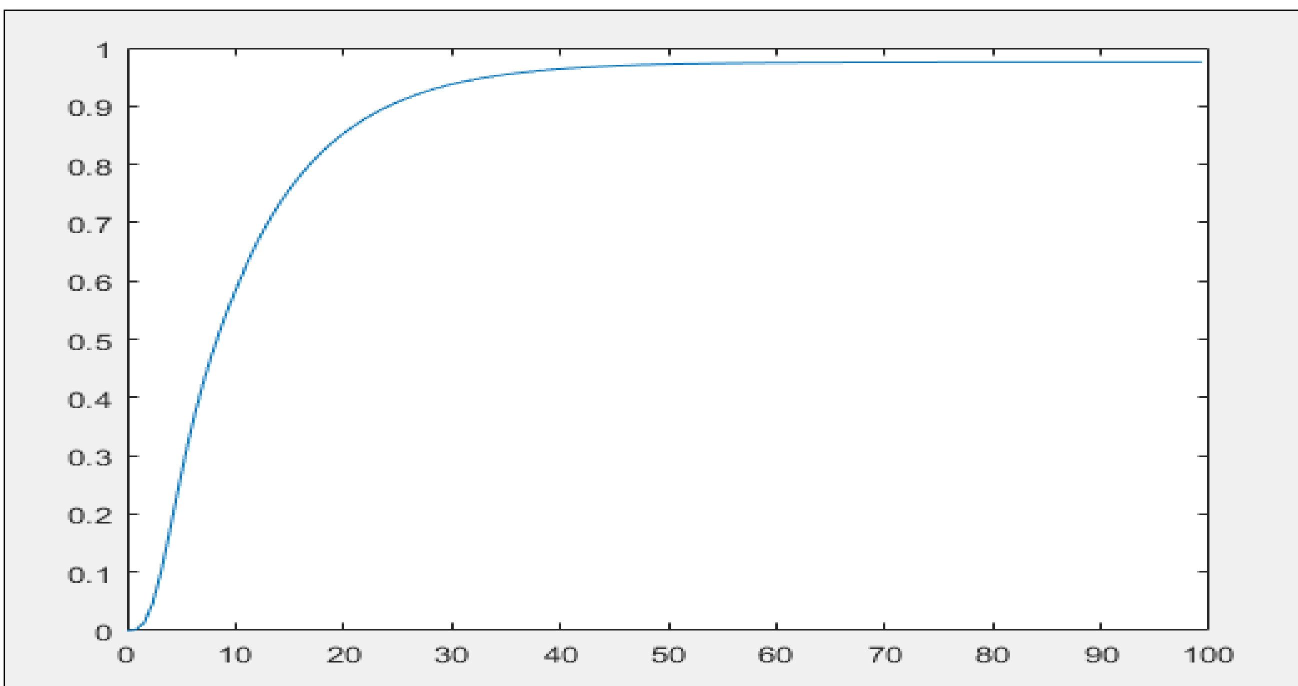


Kp value = 10

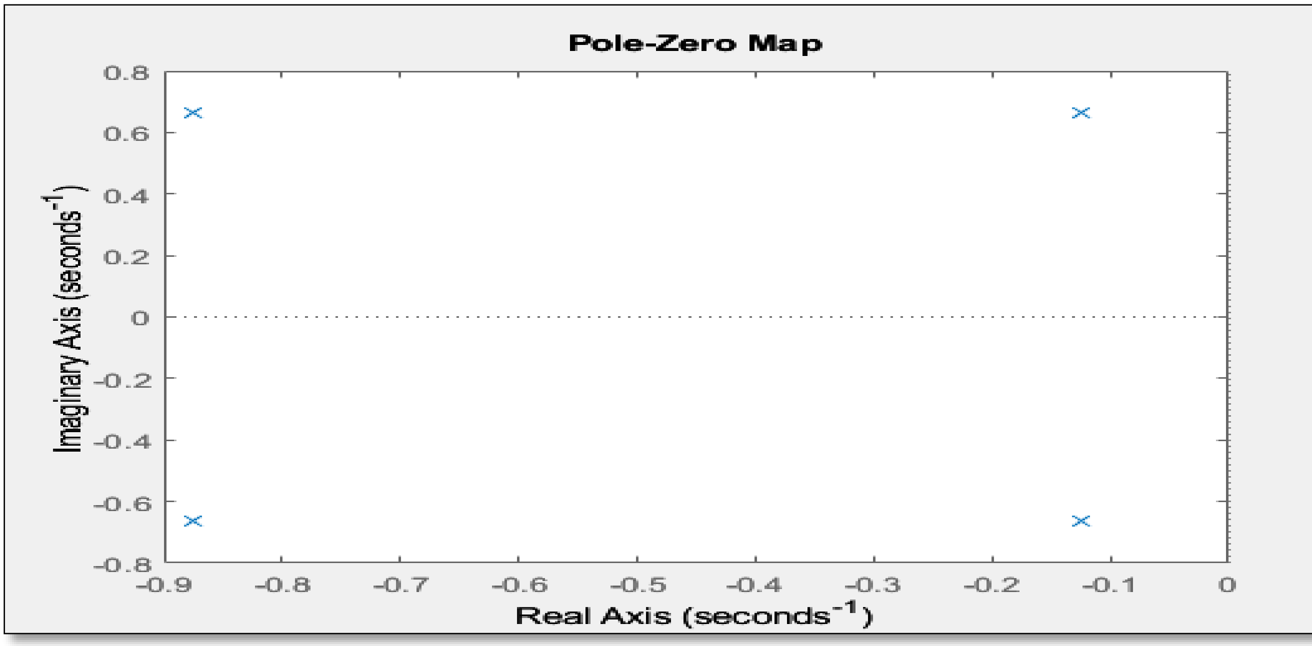


All poles are in left half plane, so the system is stable.

<u>The response of the system:</u>

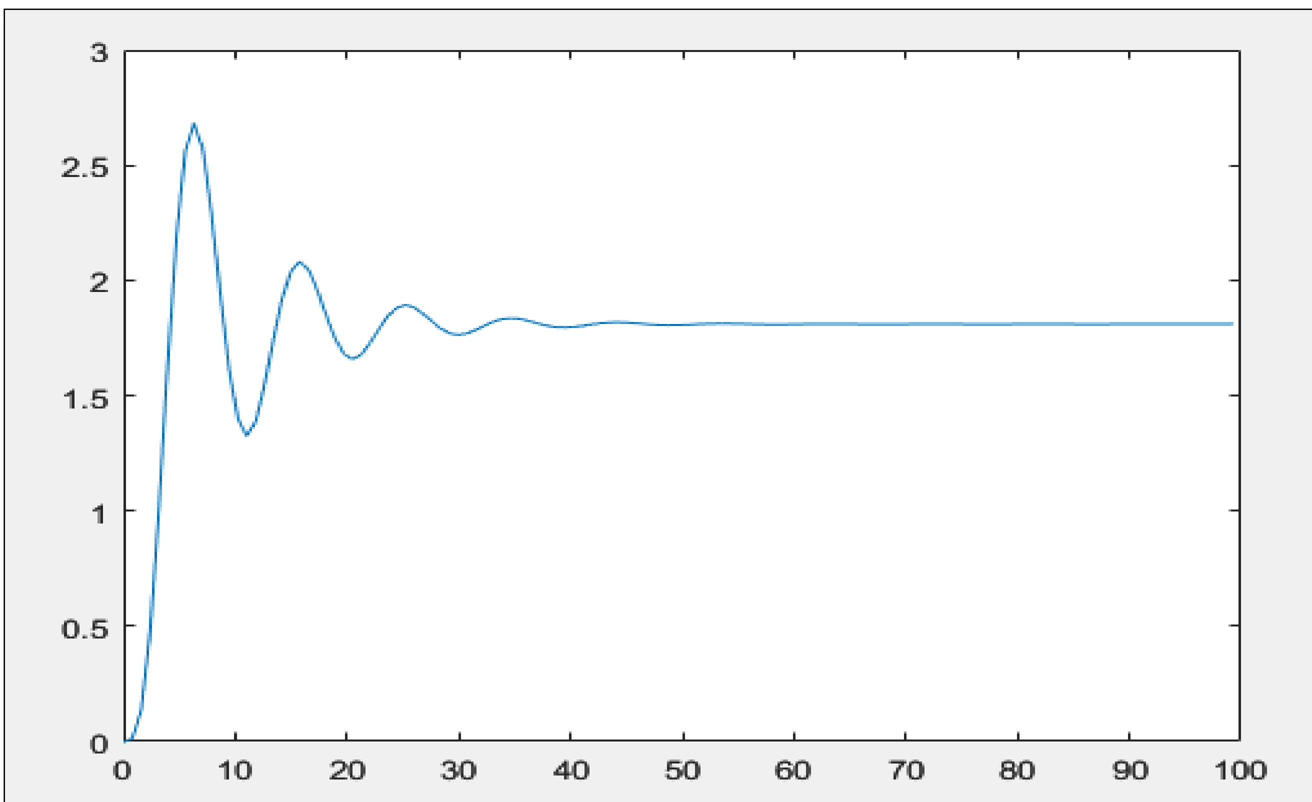


Kp value = 100

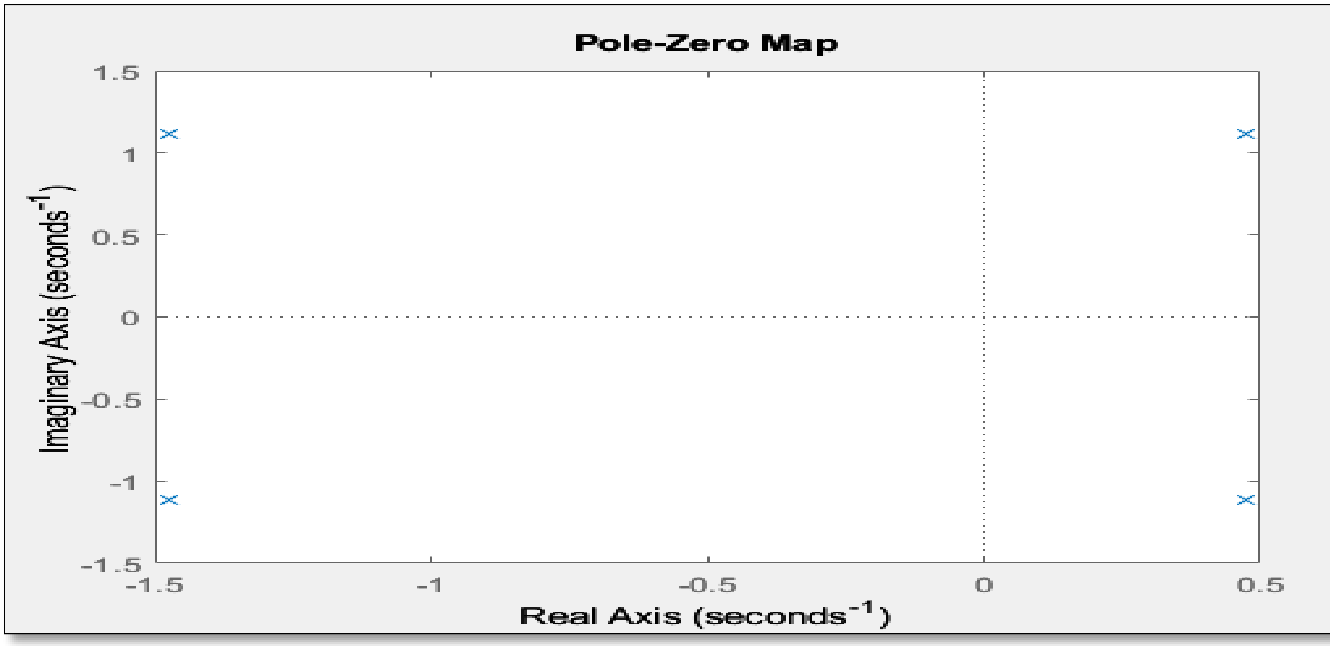


All poles are in left half plane, so the system is stable.

The response of the system:

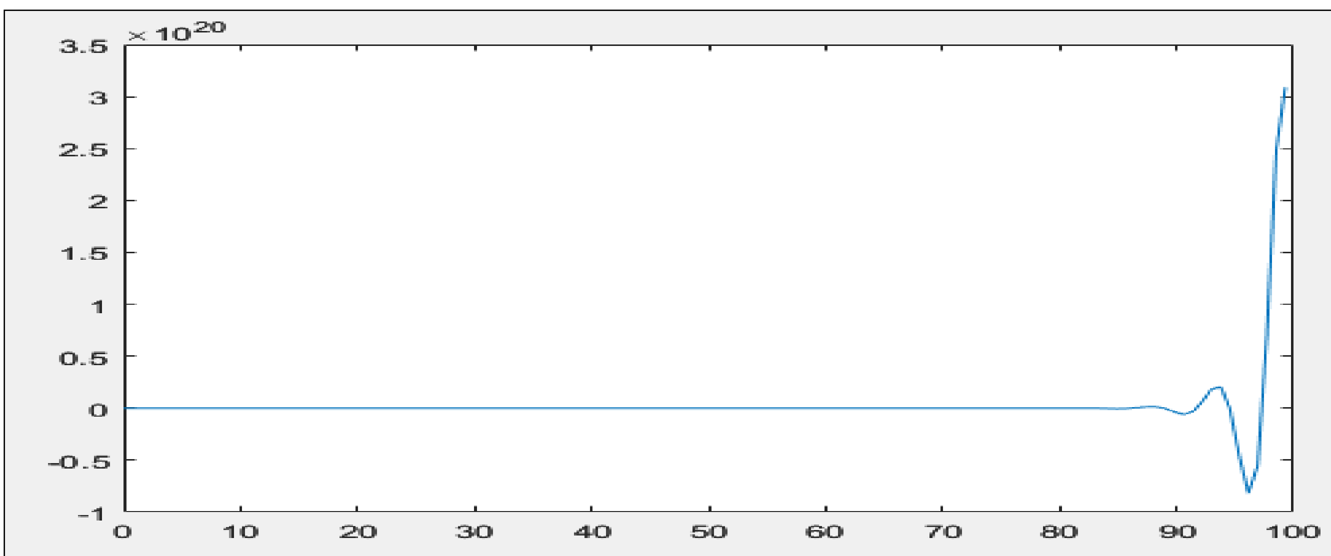


Kp value = 1000



There are some poles in the right half plane, so the system is unstable.

<u>The response of the system:</u>



Kp value = 1	Kp value = 10	Kp value = 100	Kp value = 1000
RiseTime: 37.4676 TransientTime: 68.9668 SettlingTime: 68.9668 SettlingMin: 0.0784 SettlingMax: 0.0869 Overshoot: 0 Undershoot: 0 Peak: 0.0869 PeakTime: 125.2935	RiseTime: 18.8465 TransientTime: 35.7815 SettlingTime: 35.7815 SettlingMin: 0.4393 SettlingMax: 0.4873 Overshoot: 0 Undershoot: 0 Peak: 0.4873 PeakTime: 61.3895	RiseTime: 2.2180 TransientTime: 31.0141 SettlingTime: 31.0141 SettlingMin: 0.6622 SettlingMax: 1.3416 Overshoot: 48.2520 Undershoot: 0 Peak: 1.3416 PeakTime: 6.3068	RiseTime: NaN SettlingTime: NaN SettlingMin: NaN SettlingMax: NaN Overshoot: NaN Undershoot: NaN Peak: Inf PeakTime: Inf
Steady State error : 1.82667805	Steady State error : 1.02440233	Steady State error: 0.19004232	Steady State error : 308984905426371084288
The system is stable.	**The system is stable.**	**The system is stable.**	**The system is not stable.**

Comments:

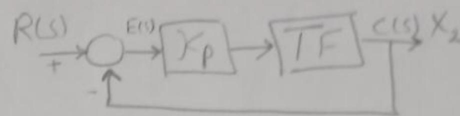
- Increasing the proportional controller gain Kp can improve the system's accuracy in reaching the desired output value (ess decreases) and speed up its response, resulting in a decreased rise time and settling time.
- However, this improvement is only observed up to a certain point (Kp = 1000), after which the system becomes unstable, and the rise time and settling time become NaN. High gains cause instability, which can affect the system's peak time.
- As Kp increases, the peak time decreases, and the overshoot increases. Therefore, there is a tradeoff between accuracy, speed, and stability when increasing Kp.

Requirement 9:

No, we cannot obtain a steady state error less than 0.01 m using proportional-only controller, because the system will not be stable (There are some poles in the right half plane).

Req ⑨:

$$TF = \frac{0.005}{s^4 + 2s^3 + 2.1s^2 + 1.1s + 0.0525}$$



$$E(s) = R(s) - C(s)\,\overset{1}{\cancel{H(s)}}$$

$$= R(s) - G(s)\,G_c(s)\,E(s)$$

$$C(s) = G(s)\,G_c(s)\,E(s)$$

$$R(s) = \frac{4}{s}$$

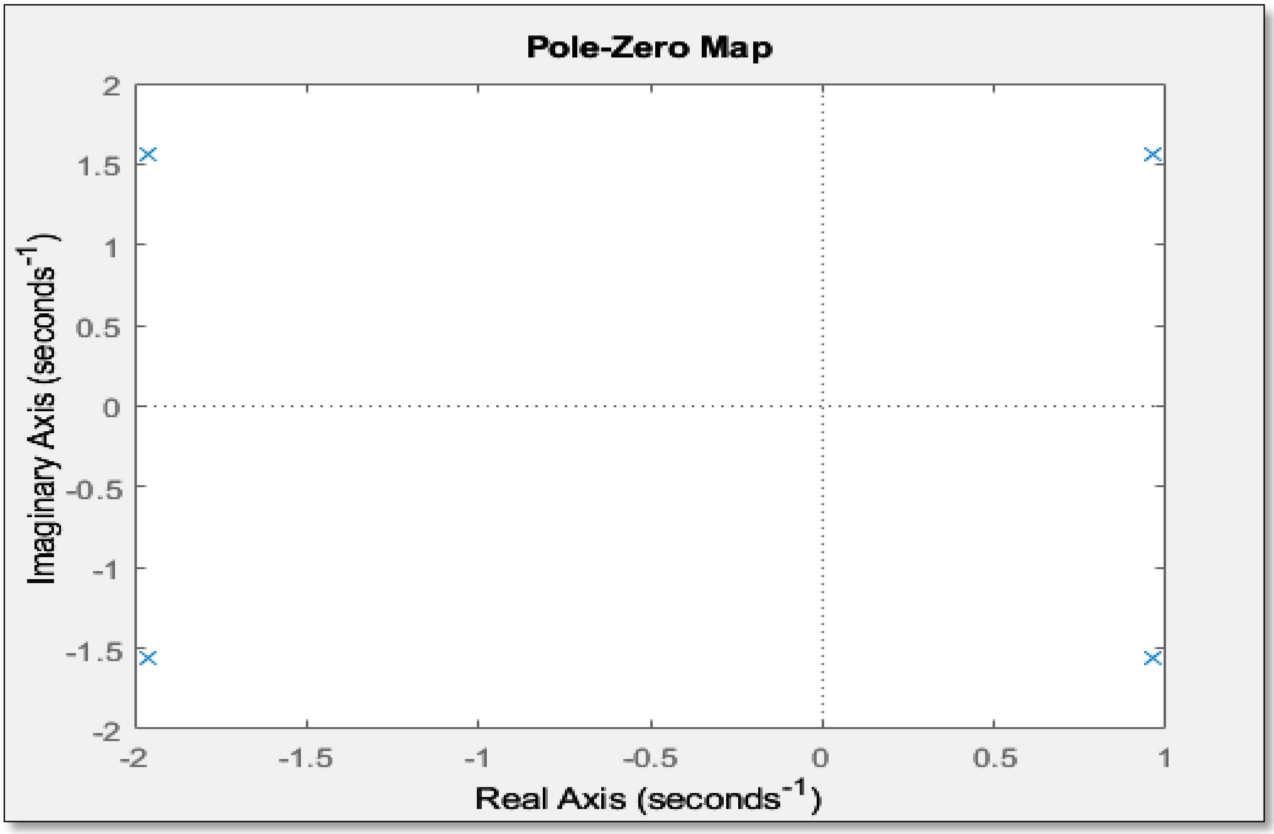
$$\therefore E(s) = \frac{R(s)}{1 + G(s)G_c(s)} = \frac{(4/s)}{1 + K_p\left(\frac{0.005}{s^4 + 2s^3 + 2.1s^2 + 1.1s + 0.0525}\right)}$$

$$e_{ss} = \lim_{s \to 0} E(s) \cdot s = \lim_{s \to 0} \frac{4(\cancel{s^4} + \cancel{2s^3} + \cancel{2.1s^2} + \cancel{1.1s} + 0.0525)}{\cancel{s^4} + \cancel{2s^3} + \cancel{2.1s^2} + \cancel{1.1s} + 0.0525 + 0.005K_p}$$

$$e_{ss} = \frac{0.21}{0.0525 + 0.005K_p} \qquad e_{ss} < 0.01$$

$$\therefore \frac{0.21}{0.0525 + 0.005K_p} < 0.01 \qquad \therefore K_p > 4189.5$$

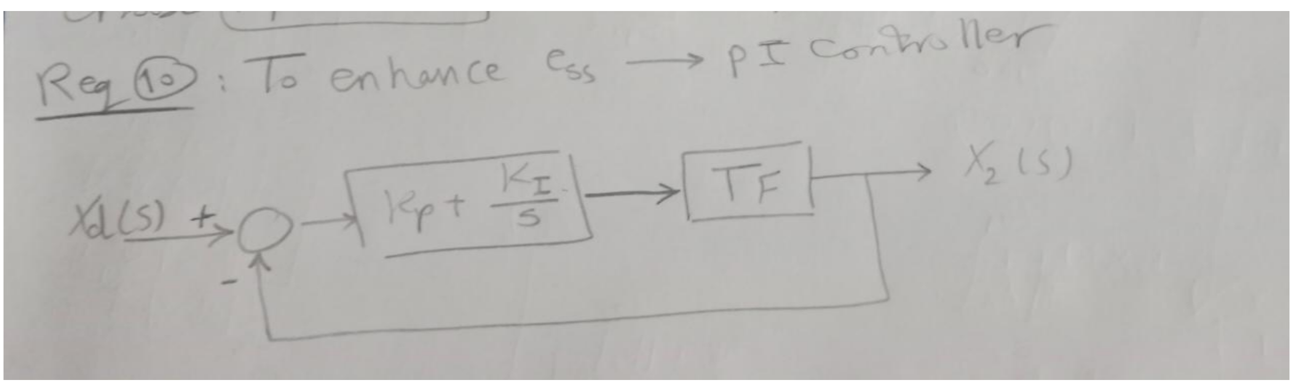
choose $\boxed{K_p = 4190}$ for example



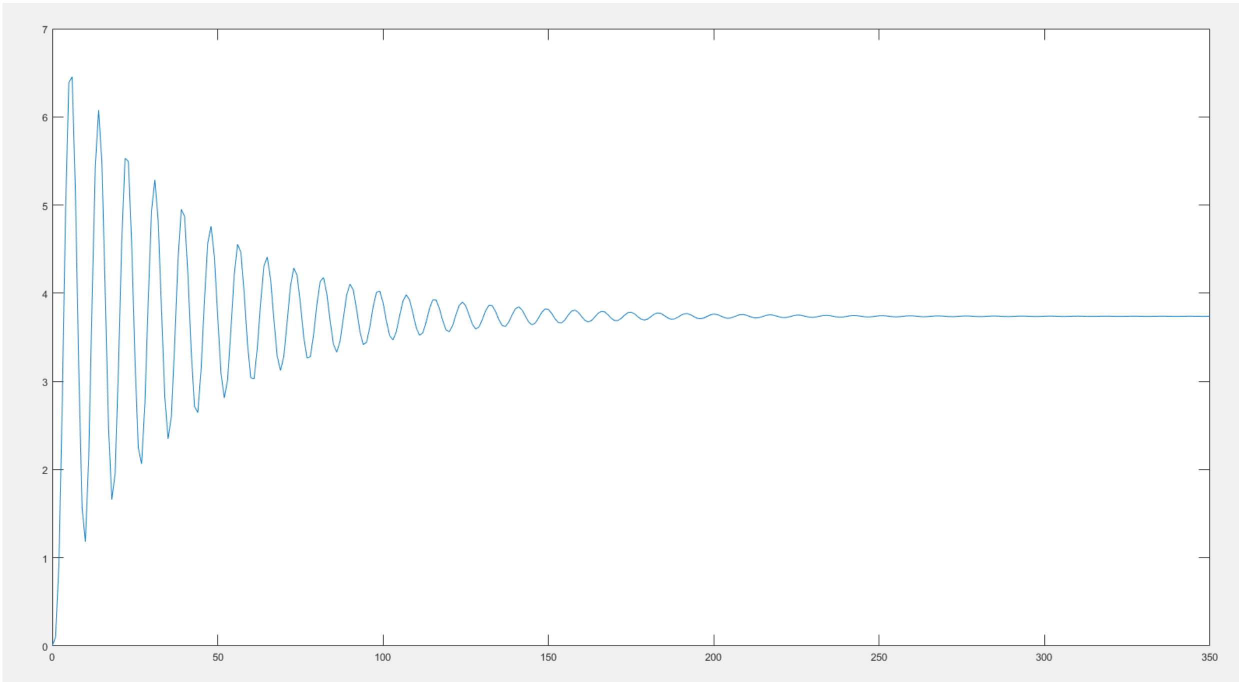
Requirement 10:

Kp = 150
Ki = 9.7

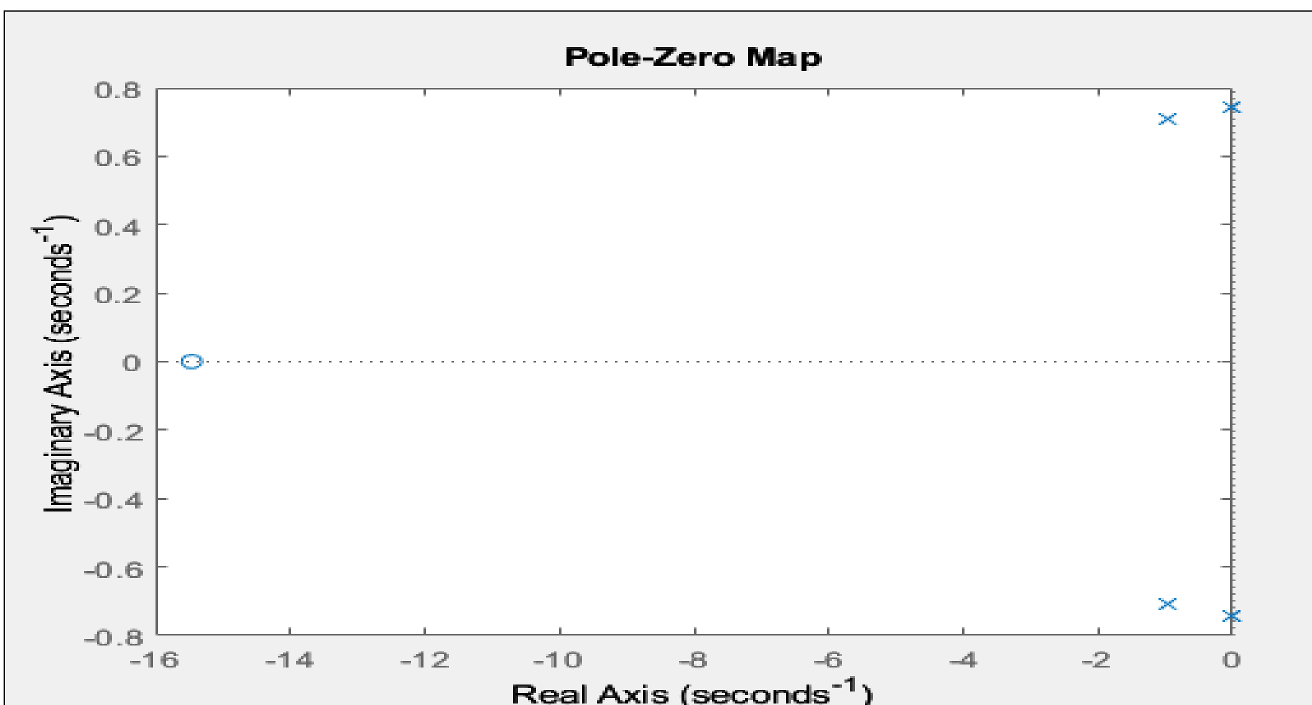
we got these values by try and error.



The system response:



The stability of the system:



As shown in the last Figure, the system is stable (all poles are in the left half plane even the 2 poles on the right that seems to be on the zero axis but they are not on the zero, they really on the left half plane).