Temperature Control using PID controller

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Contents:

PID Controller

Definition:

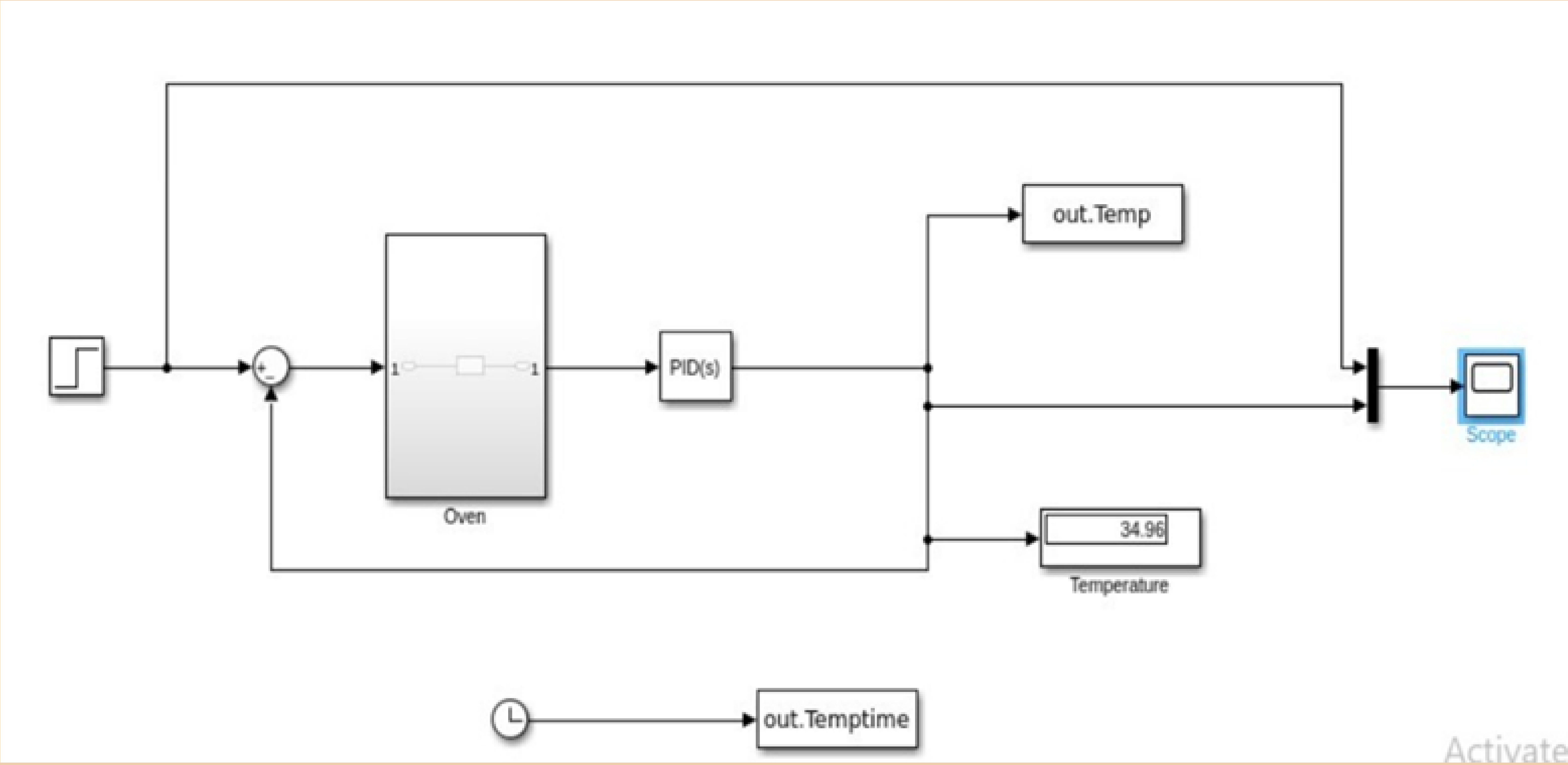
->A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control.

-> A PID controller continuously calculates an error value.

Constants:

Kp	proportional gain
Kd	derivative constant
Ki	integral constant

Simulink setup:



Process

Step 1

-> we derived our system transfer function which is shown as an 'oven'

Step 2

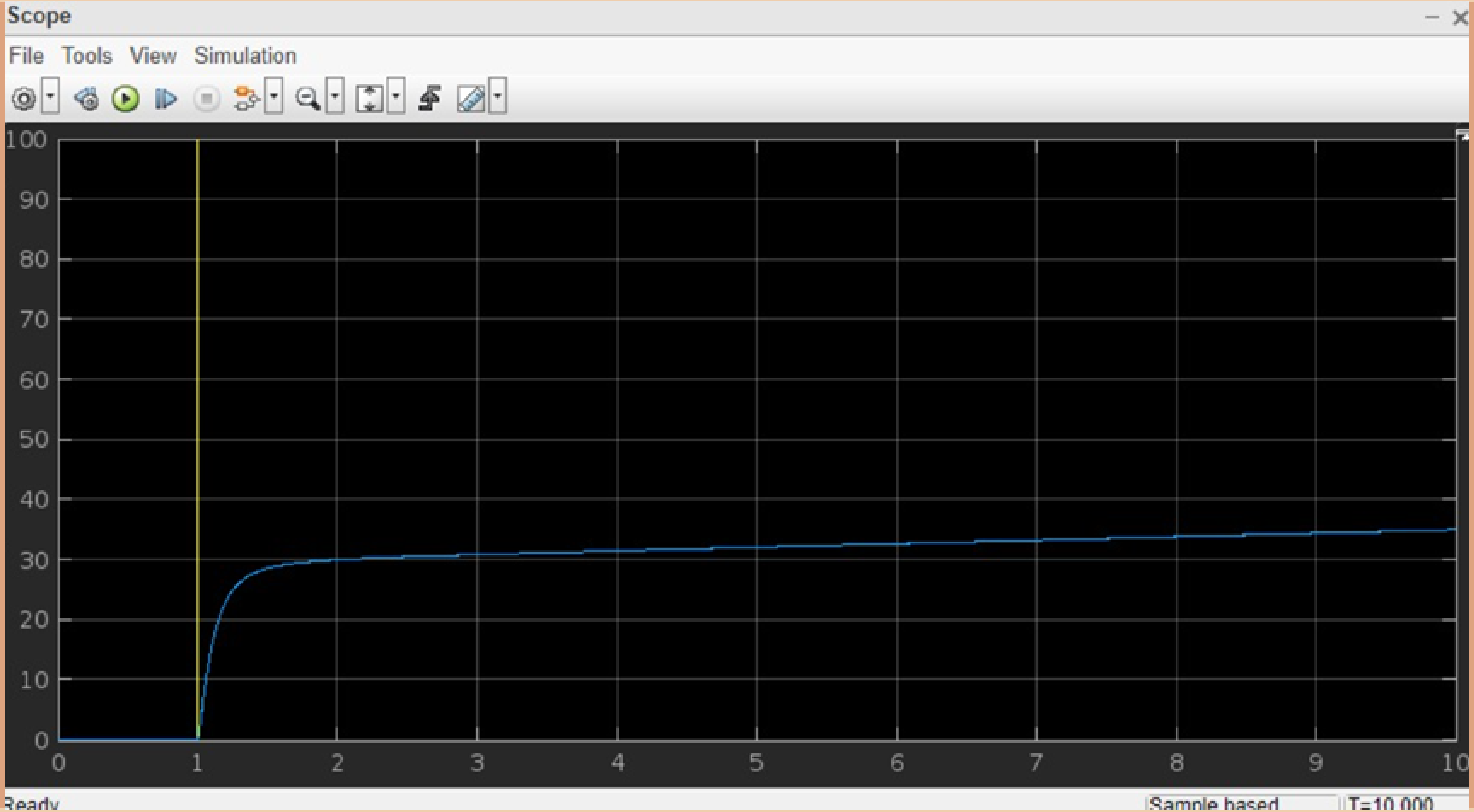
-> we applied different inputs such as step inputs

Step 3

-> fed everything into an oscilloscope to get our variation of temperature of the system

Note: we control the temperature by controlling the Kp/Ki/Kd constants

Temperature control:



Implementation of Project 3 questions

Question 1:

1. The objective of this experiment is to analysis and design of control systems specific to a physical system. Each student will be given a specific physical system, and experiments are to be conducted on that particular physical system. (The specific physical system will be given to a student by the respective Teacher or Student can select the physical system by themselves.)
    a. The objective of this exercise is to obtain the open loop characteristics of the given transfer function of the physical system or plant. (i) Where are the poles and zeros located? Obtain the pole-zero map. (ii) Apply different test signals, and observe the time-domain response. Discuss the results obtained from the viewpoint of pole-zero map.

OUTPUT (Q1)

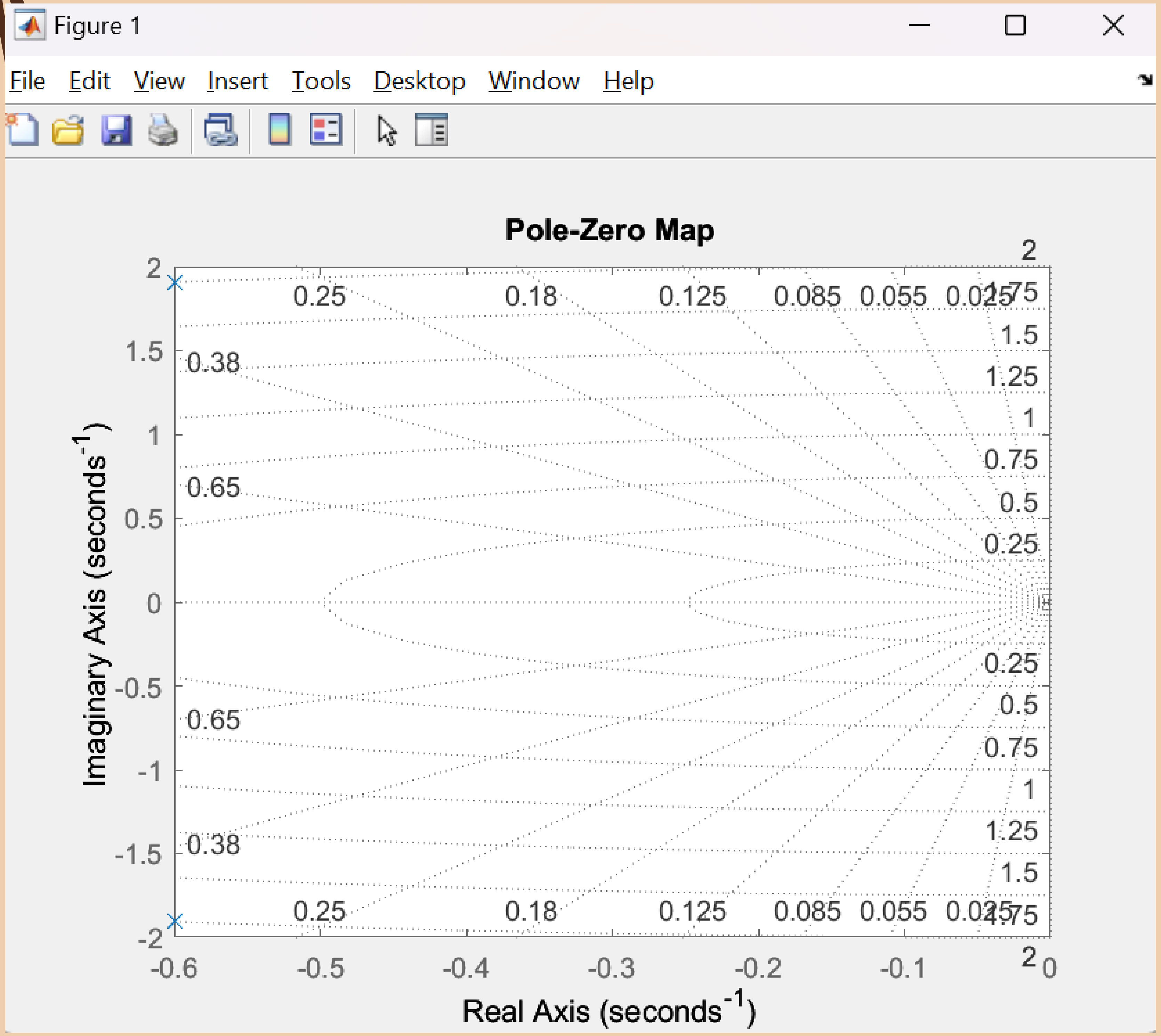


Figure 1
File Edit View Insert Tools Desktop Window Help
Pole-Zero Map
Imaginary Axis (seconds^{-1})
Real Axis (seconds^{-1})
0.25 0.18 0.125 0.085 0.055 0.025
0.38
0.65
-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0
2 1.5 1 0.5 0 -0.5 -1 -1.5 -2
1.75 1.5 1.25 1 0.75 0.5 0.25

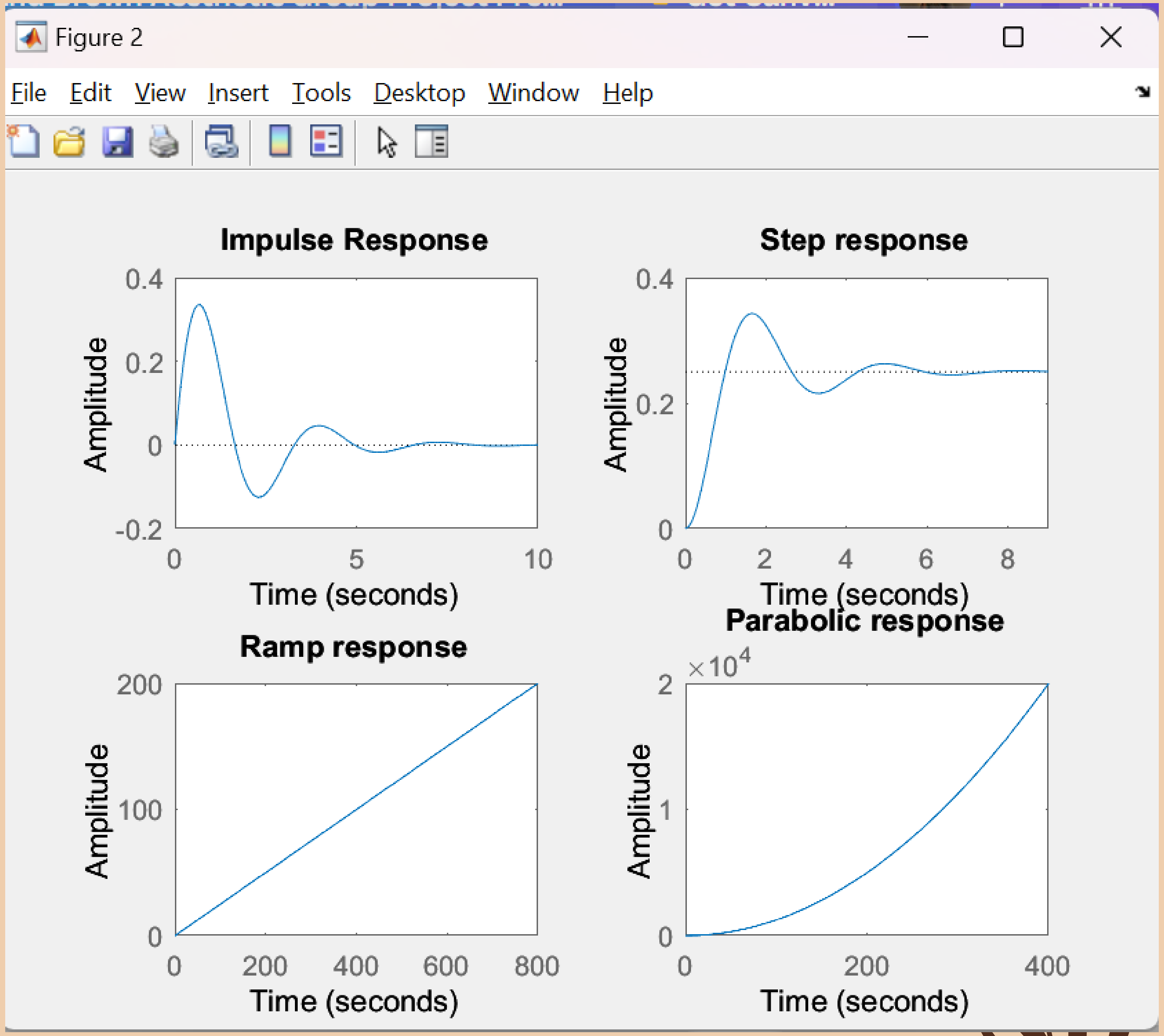


Figure 2
File Edit View Insert Tools Desktop Window Help
Impulse Response
Step response
Ramp response
Parabolic response
Amplitude
Time (seconds)
$\times 10^4$

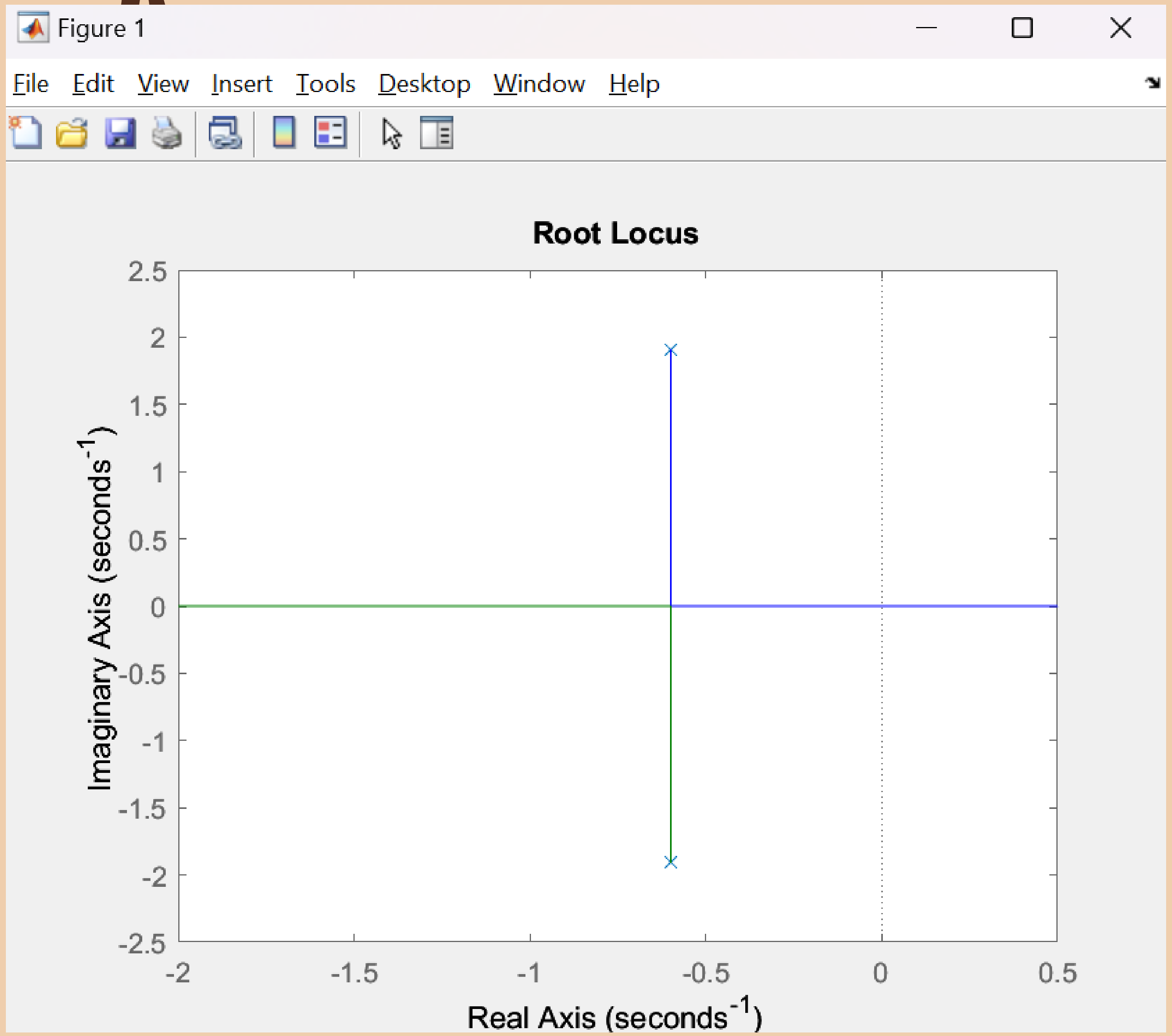
OUTPUT (Q1)

```
Poles:
  -0.6000 + 1.9079i
  -0.6000 - 1.9079i


Zeros:
>>
```

Question 2:

2. The objective of this exercise is to determine the range of a gain that assures closed loop stability. Assume that the given system is part of a unity negative feedback system, and there is a gain in cascade with the given system in the forward path. Conduct experiments similar to **(project2-1)** and determine the range of k for which the closed loop system is stable.

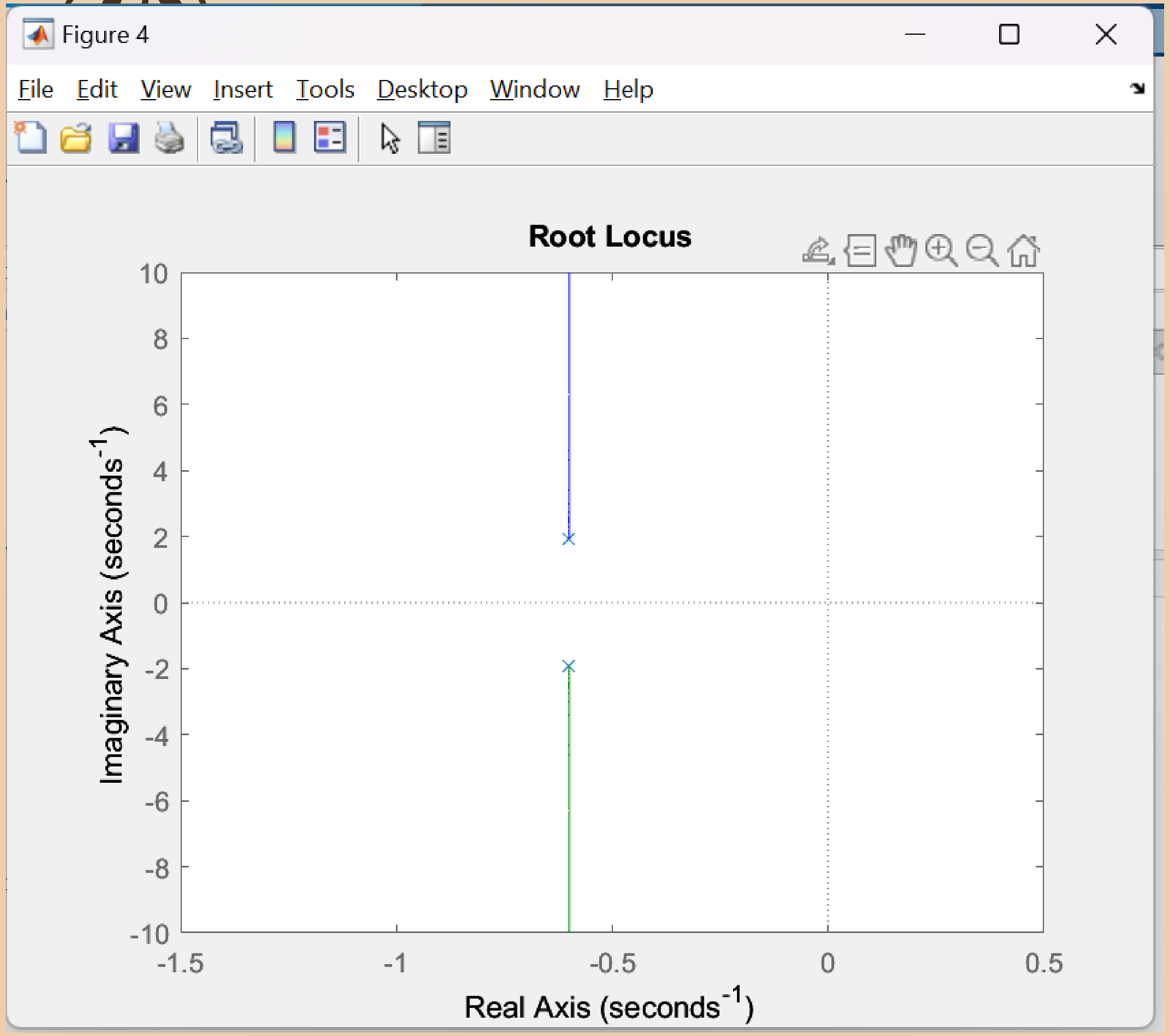
OUTPUT (Q2)



Unstable System

```
sys =

        -20
  ---------------
  s^2 + 1.2 s + 4

Continuous-time transfer function.
```

OUTPUT (Q2)



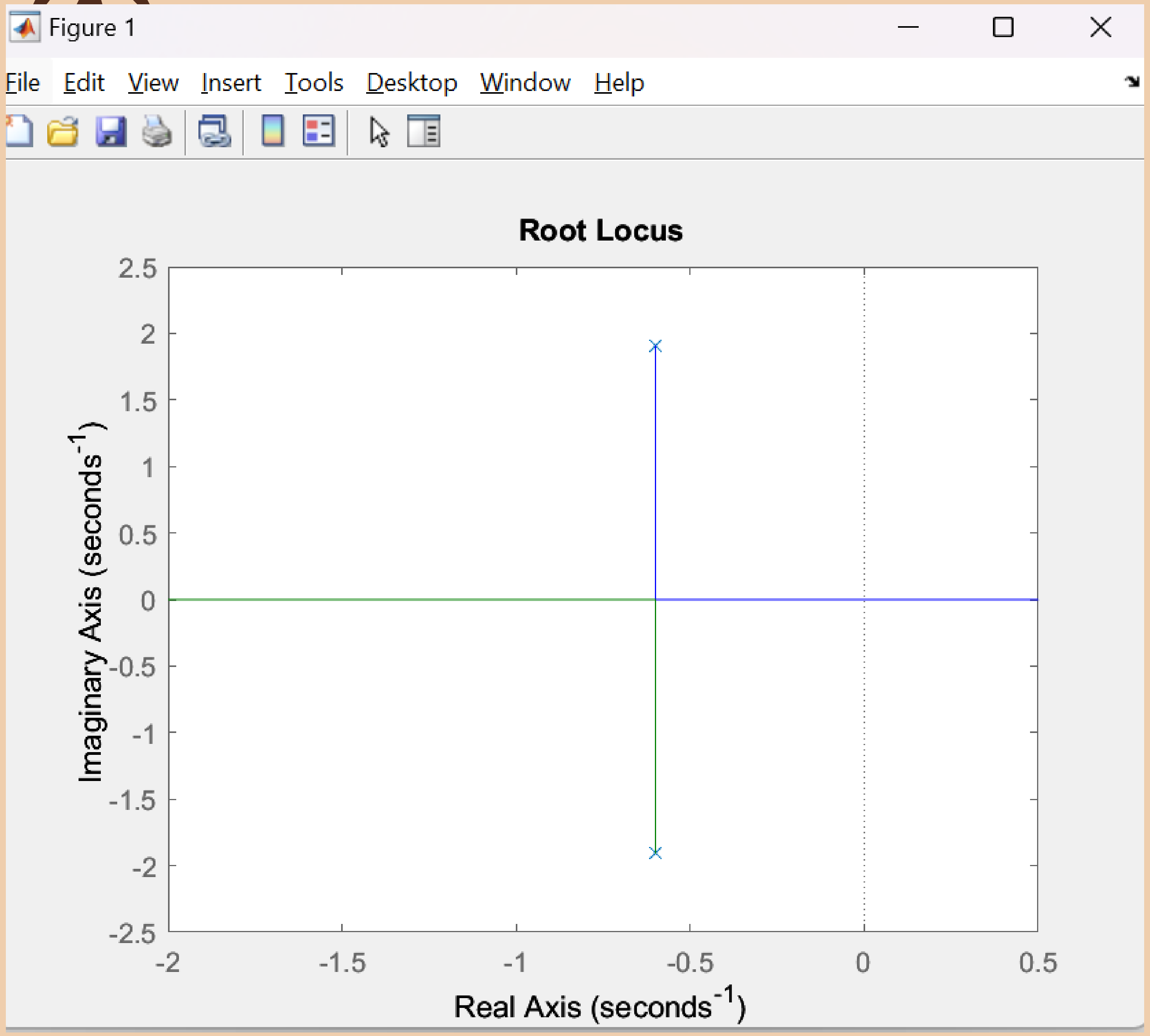

```
sys =

        10
  ---------------
  s^2 + 1.2 s + 4

Continuous-time transfer function.
```

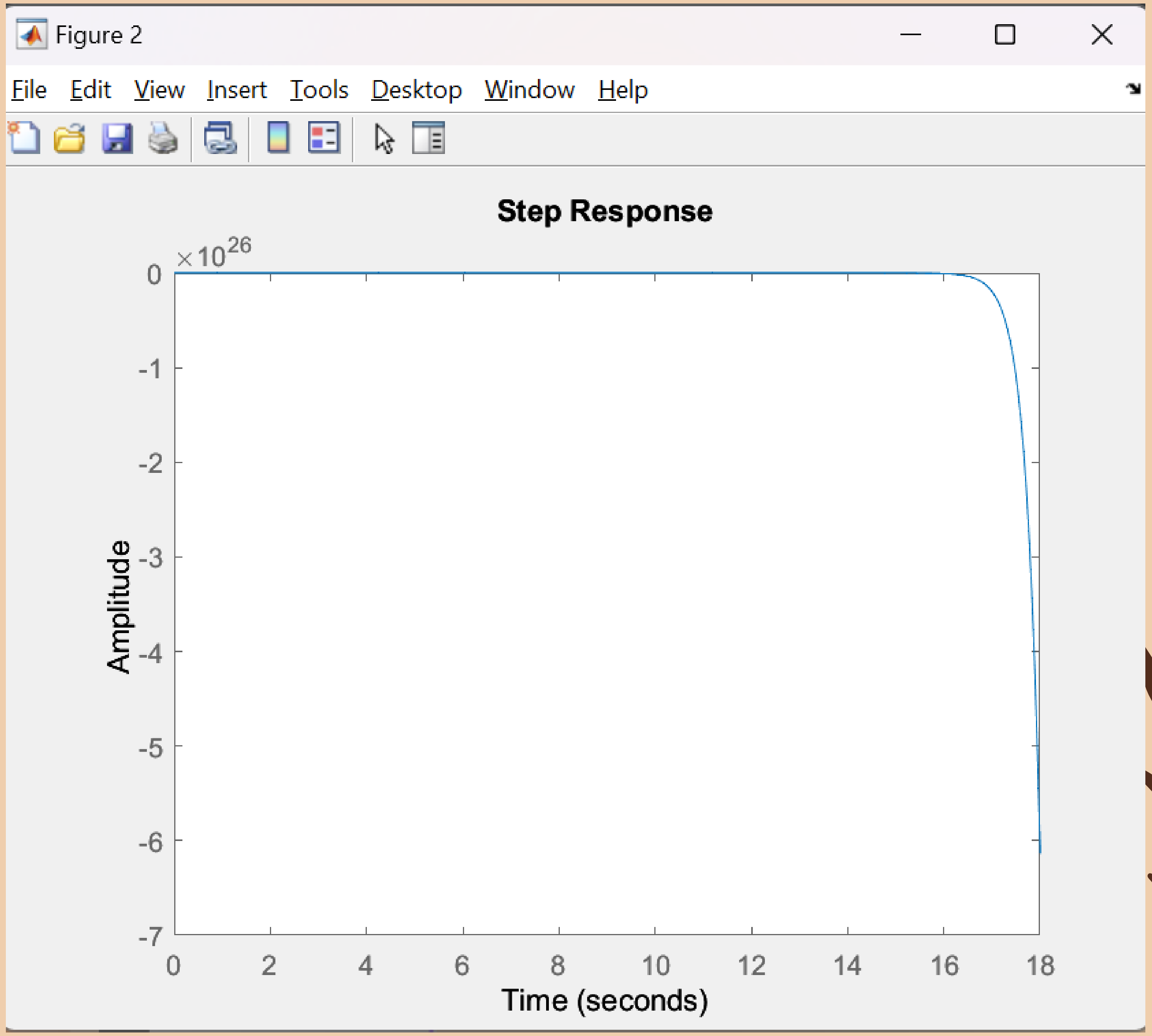
Stable System

Question 3:

3. The objective of the exercise to analyse the closed loop system behaviour with proportional controller of the system whose transfer function you were given earlier.
   a. Place a gain *k* in the forward path, and close the loop with negative unity feedback. Take different values for *k*. For each value of in this set, obtain the step response. What is the rise time, the settling time? Are there any oscillations? If so, what is the frequency of oscillation? Compare the response of the closed loop system to the open loop system. Compare the closed loop responses. Discuss the results. Can we increase *k* indefinitely?
   b. Obtain the root locus. Mark the earlier choices of *k* on the root locus. Discuss the results obtained from the root locus with reference to those obtained with *k* in the forward path in part 3(a).

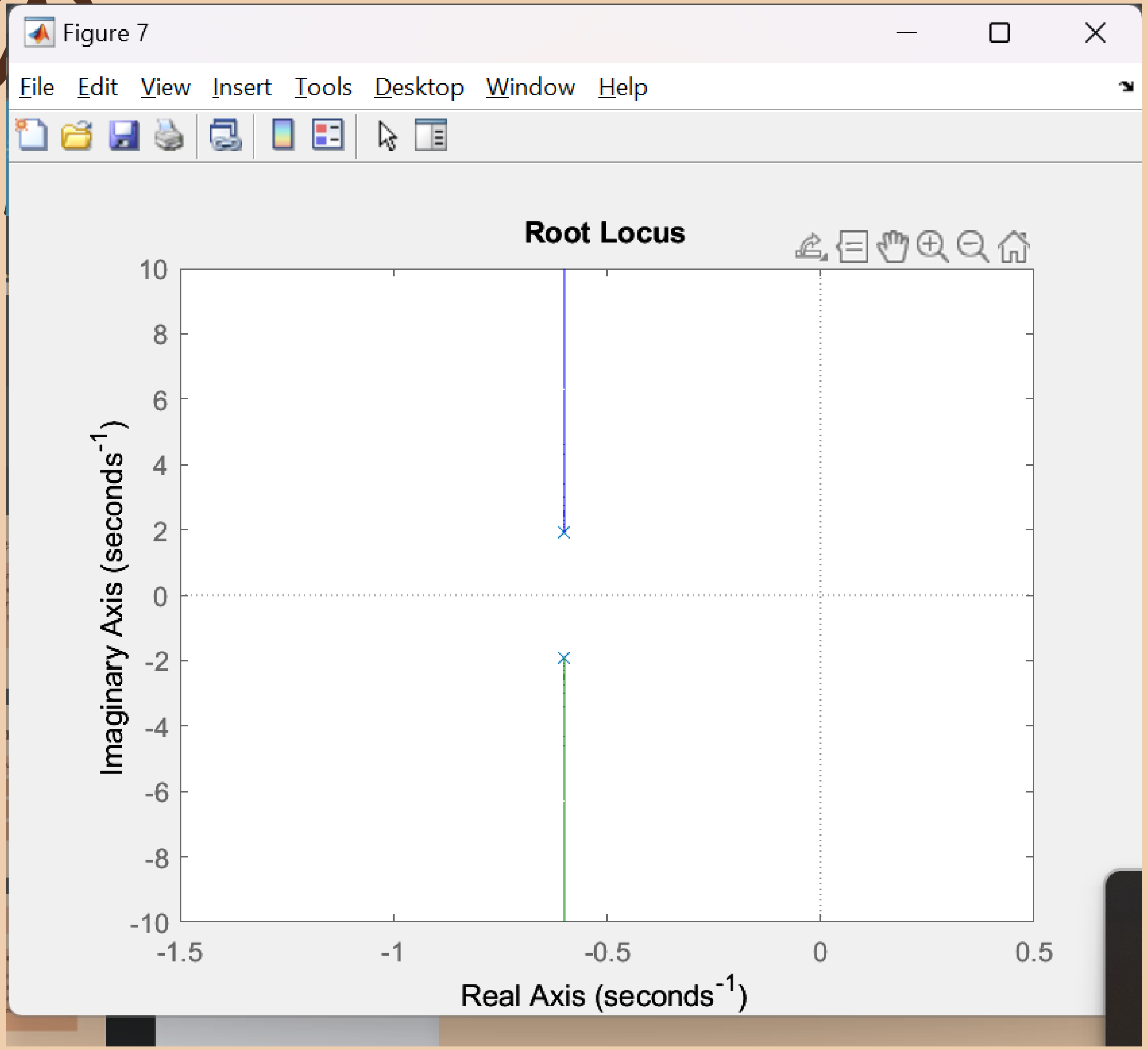
OUTPUT (Q3)

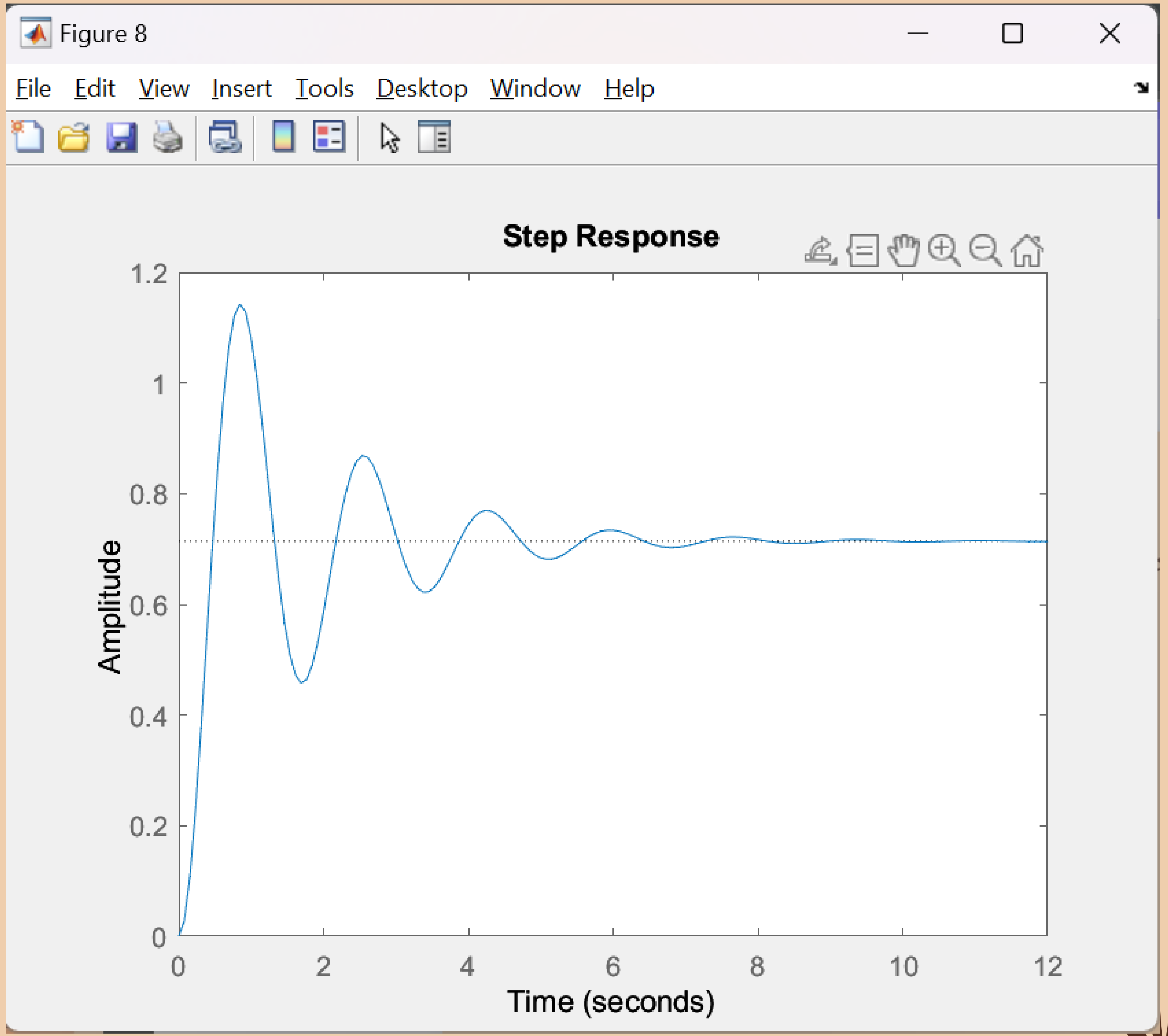




Unstable System

OUTPUT (Q3)





StableSystem

OUTPUT (Q3)

```
struct with fields:

        RiseTime: 0.3163
   TransientTime: 6.1698
    SettlingTime: 6.1698
     SettlingMin: 0.4572
     SettlingMax: 1.1429
       Overshoot: 60.0097
      Undershoot: 0
            Peak: 1.1429
        PeakTime: 0.8443
```

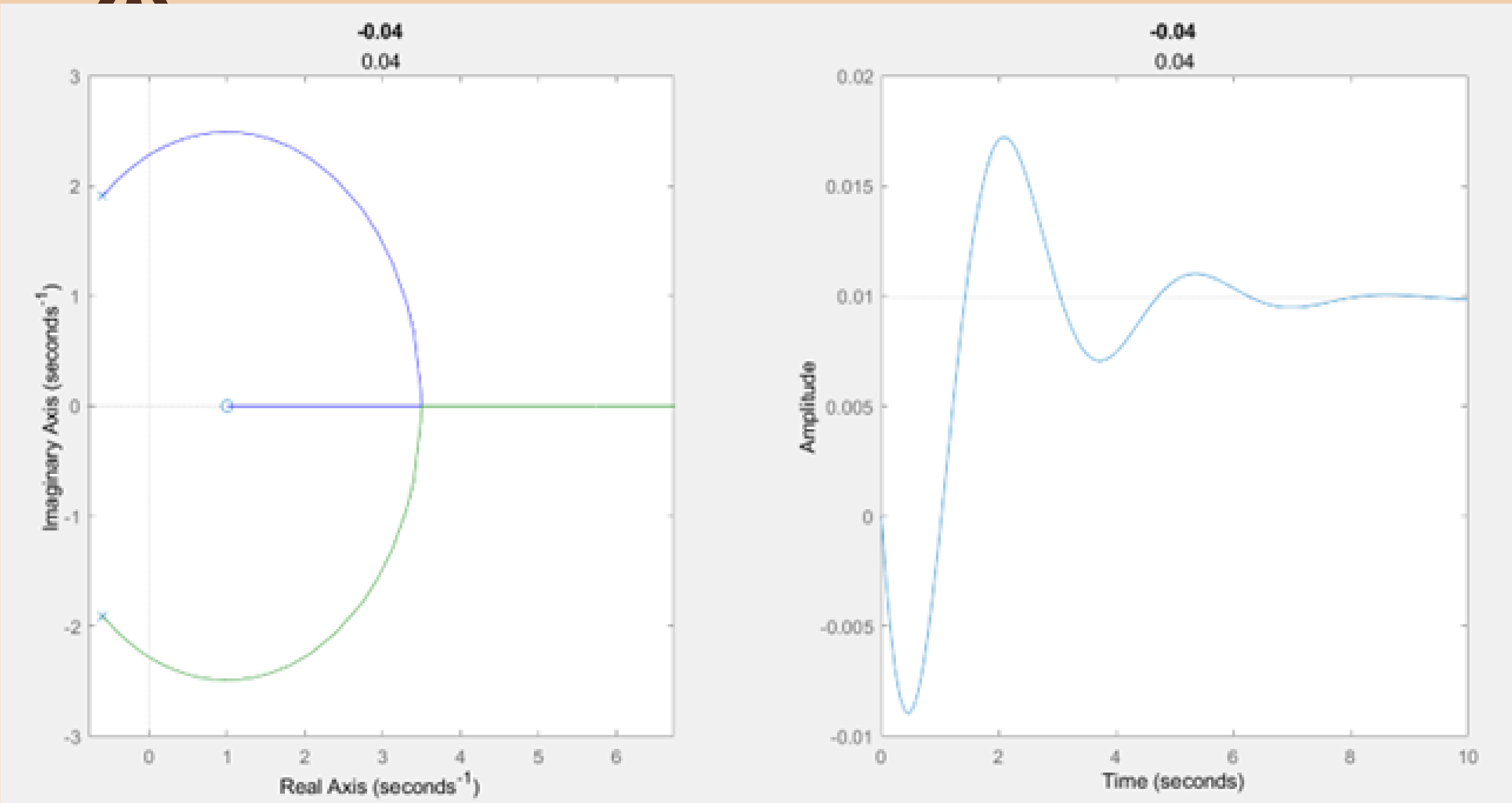
inference

- Regarding response, the closed-loop system has a faster response time and a smaller steady-state error than the open-loop system.
- No, the gain parameter, k, cannot be increased indefinitely in a closed-loop system response because it might induce system instability.
- The root locus plot demonstrates how the positions of the closed-loop poles in the complex plane change as the gain parameter, k, is adjusted.
- The closed-loop poles on the root locus plot move as k rises until they either approach one another or move into the right half of the complex plane, indicating instability.

Question 4:

4. The objective of this exercise is to obtain the closed loop behaviour with proportional plus derivative controller of the system you were given earlier. Place a function K (s + z) in the forward path, and close the loop with negative unity feedback. Take different values for K and z. For each sets of (K,z) obtain the step response, and the rlocus. Compare the step response for each case, and compare with the case of putting only a gain K in the forward path. What is therefore the effect of adding a zero in the forward path? Are there any additional insight to be gained from the rlocus: Obtain the root locus for each case. Compare the three loci, and discuss the results.

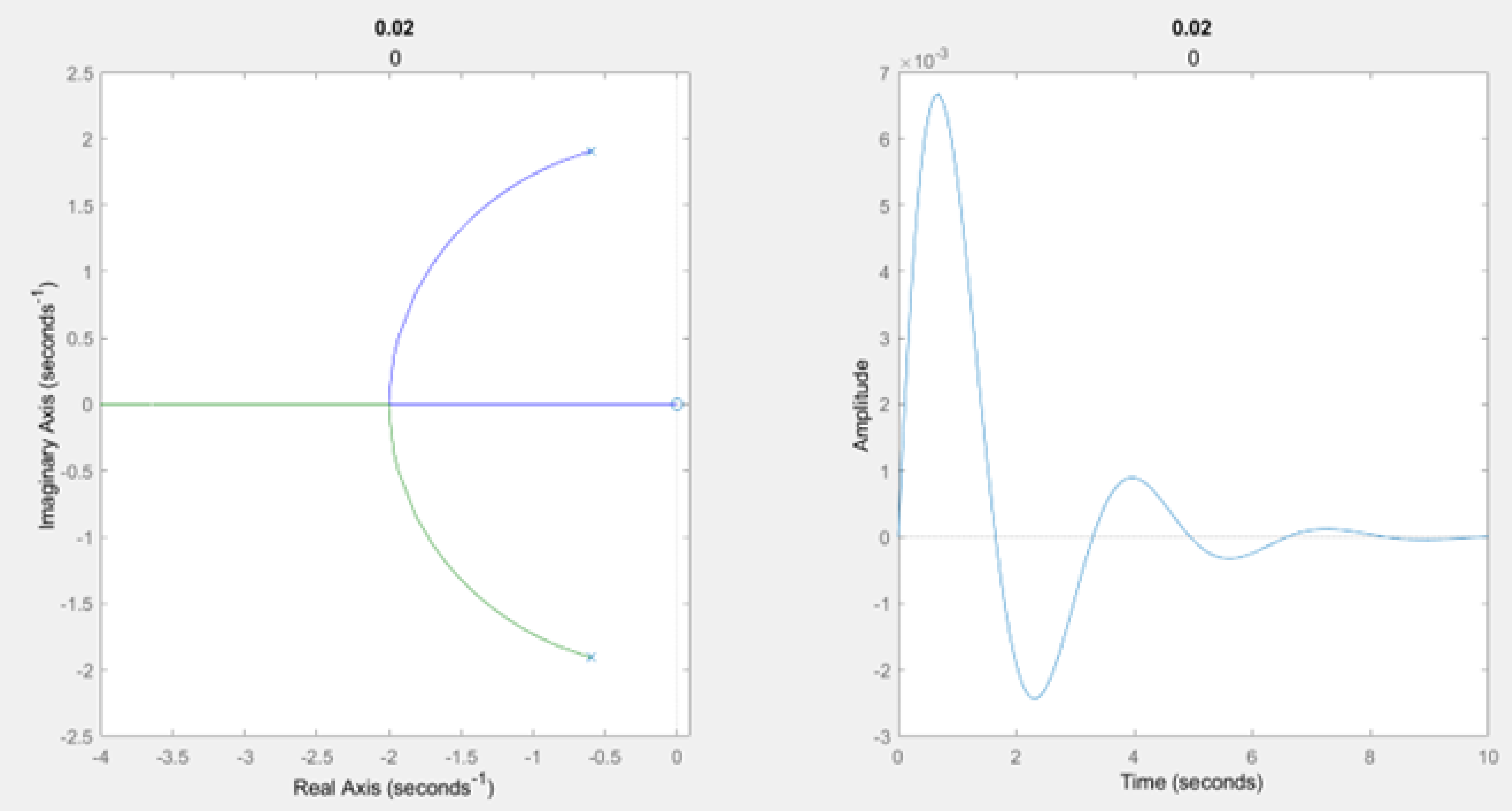
OUTPUT (Q4)




```
inf =

  struct with fields:

        RiseTime: 0.3185
   TransientTime: 7.2434
    SettlingTime: 7.6014
     SettlingMin: 0.0071
     SettlingMax: 0.0172
       Overshoot: 73.9136
      Undershoot: 90.6817
            Peak: 0.0172
        PeakTime: 2.0644
```

Unstable System

OUTPUT (Q4)




```
inf =

  struct with fields:

        RiseTime: 0
   TransientTime: 6.2619
    SettlingTime: NaN
     SettlingMin: -0.0048
     SettlingMax: 0.0133
       Overshoot: Inf
      Undershoot: Inf
            Peak: 0.0133
        PeakTime: 0.6685
```

Stable System

inference

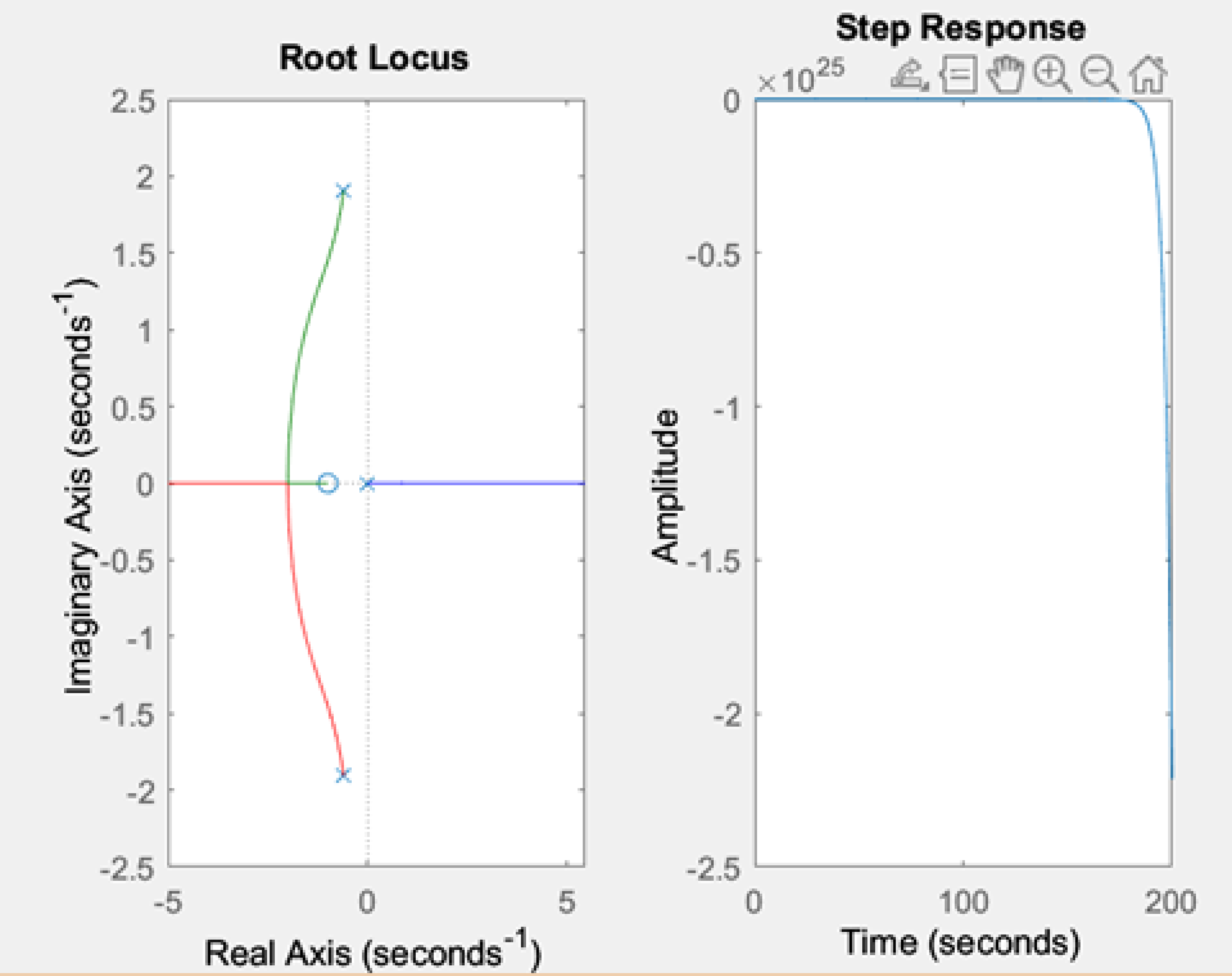
- The system is stable for k value >-1.2 and kz value > -4

Derivative(Zero) softens or smooths oscillations , ie., it damps the system’s response making it more stable.

Question 5:

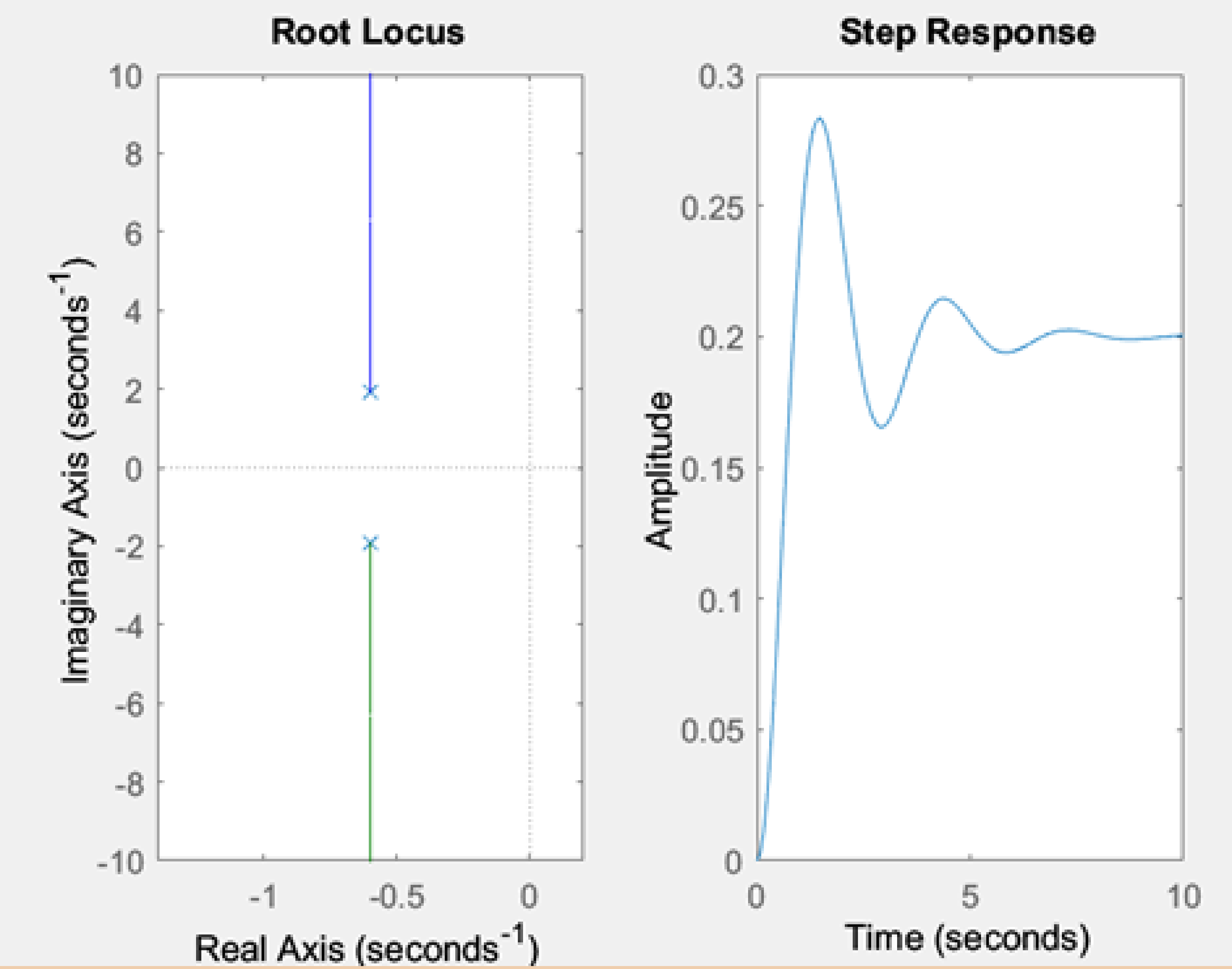
5. (a)The objective of this exercise is to obtain the closed loop behaviour with proportional plus integral controller of the system you were given earlier. (i) Place a function $K((s+z)/s)$ in the forward path, and close the loop with negative unity feedback. Take different values for K and z, For each sets of (K, z)obtain the step response, and the root locus. Compare the step response for each case, and compare with the case of putting only a gain Kin the forward path and $K(s+z)$. What is therefore the effect of adding a pole in the forward path? Are there any additional insights to be gained from the root locus. Compare the three loci, and discuss the results. Hence (ii) infer the

OUTPUT (Q5a)



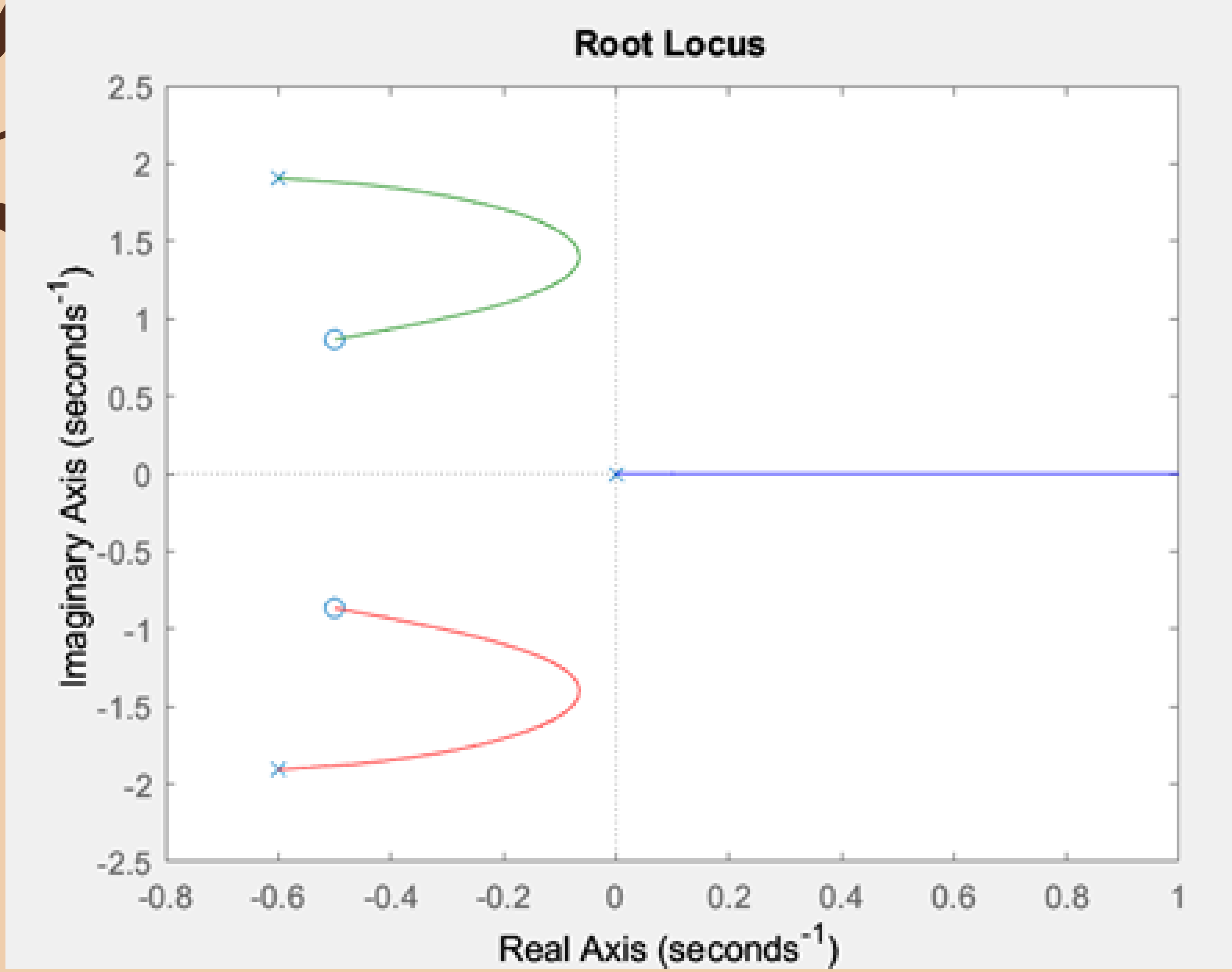
Unstable System

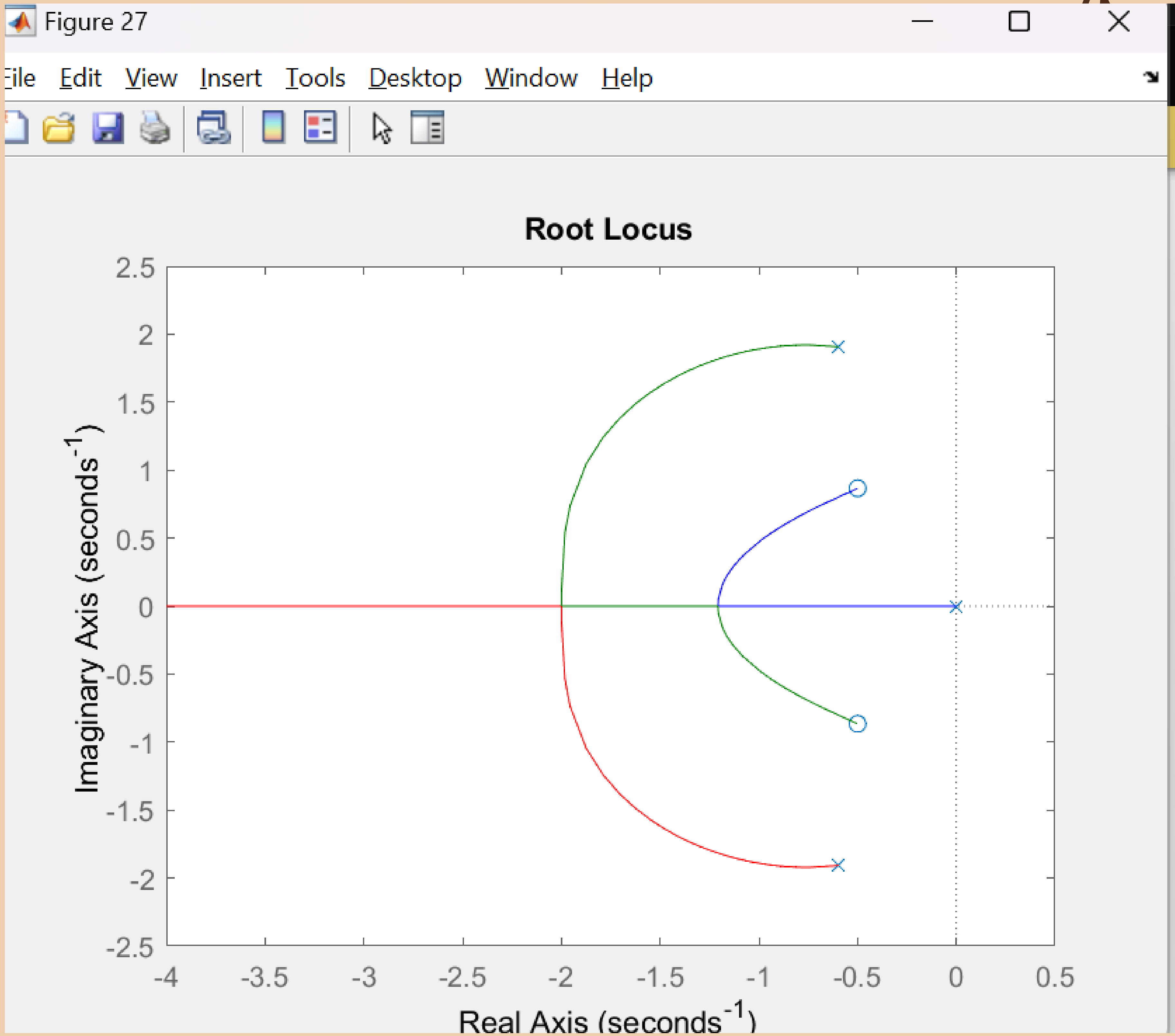
OUTPUT (Q5a)



Stable System

Output 5b:





Unstable System

Stable System

inference

- The effect of adding a pole in the forward path is to introduce a time delay in the system's response. This can result in slower response and longer settling time, as the system takes longer to reach its steady-state value.
- A P controller's root locus consists of a single branch, whereas a PD controller has two branches and a PID controller has three branches. The complexity of the controller increases the number of branches of the root locus. The derivative term in the controller responds faster to changes in the error signal, reducing overshoot and improving transient response. However, it can also make the system more sensitive to noise and disturbances, causing the closed-loop poles to shift to the right side of the complex plane and destabilise the system.

Question 6:

6. (b) The objective of this exercise is to analyse the system in frequency-domain. Obtain the Bode and Nyquist plot for the system you were given earlier. What are the gain and phase margins? What can you conclude about the stability of your system?

The objective of this exercise is to obtain the closed loop behaviour with Lead or Lag compensator of the system you were given earlier. (i) Place a function $\frac{K(\tau s+1)}{\alpha(\alpha\tau s+1)}$ in the forward path, and close the loop with negative unity feedback for Lag compensator and $\frac{K(\alpha\tau s+1)}{\alpha(\tau s+1)}$ for Lead compensator. For fixed K, take different values for α and τ, For each sets of (α, τ)obtain the Bode and Nyquist plots of the modified transfer function. Determine the phase and gain margins and also determine the step response of the closed loop transfer function. In addition, obtain the root locus plot. Discuss the results, and draw conclusions. Compare the results with P, PD in the forward path.

OUTPUT (Q6a)

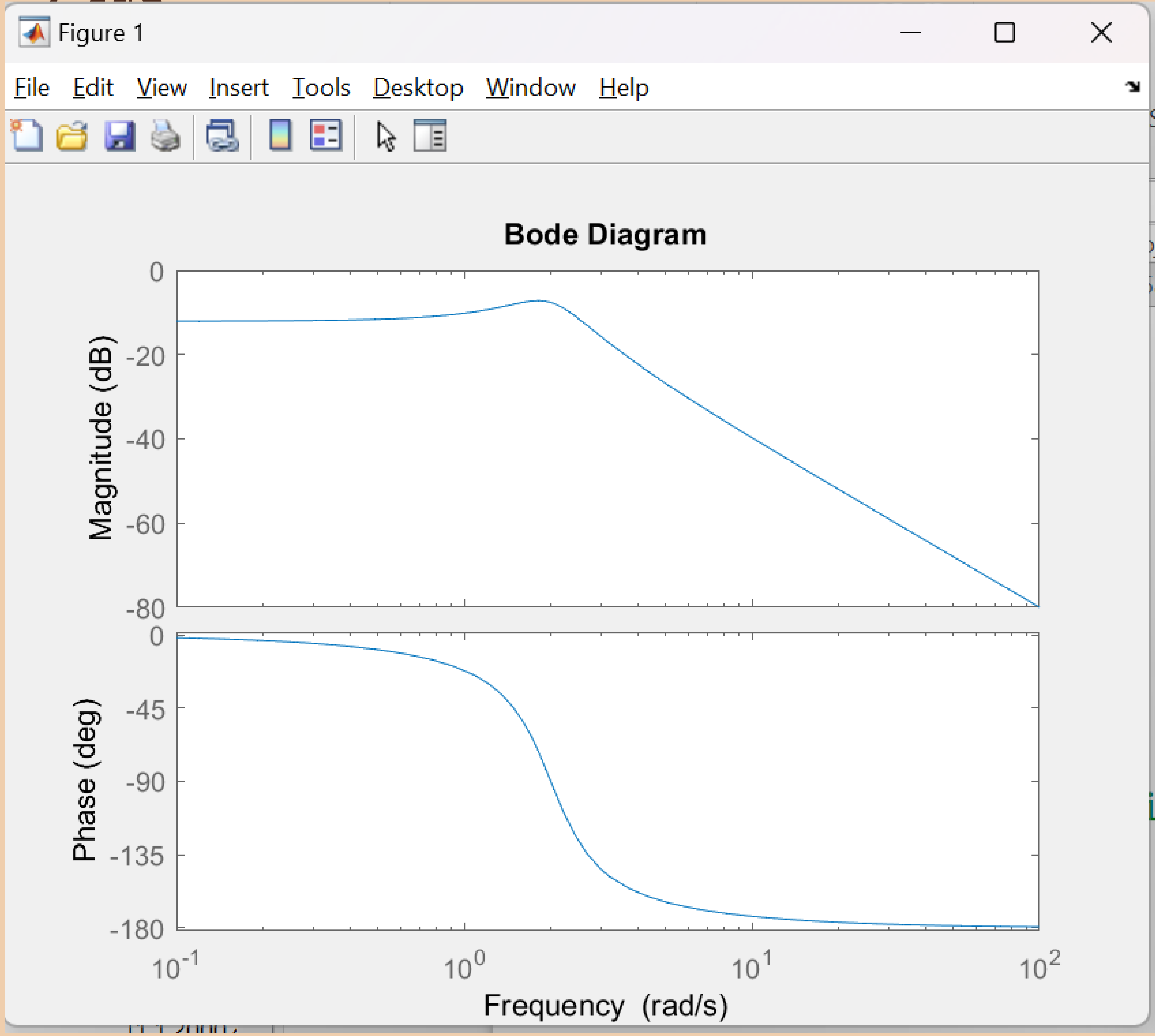


Figure 1
File Edit View Insert Tools Desktop Window Help
Bode Diagram
Magnitude (dB)
0
-20
-40
-60
-80
Phase (deg)
0
-45
-90
-135
-180
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency (rad/s)

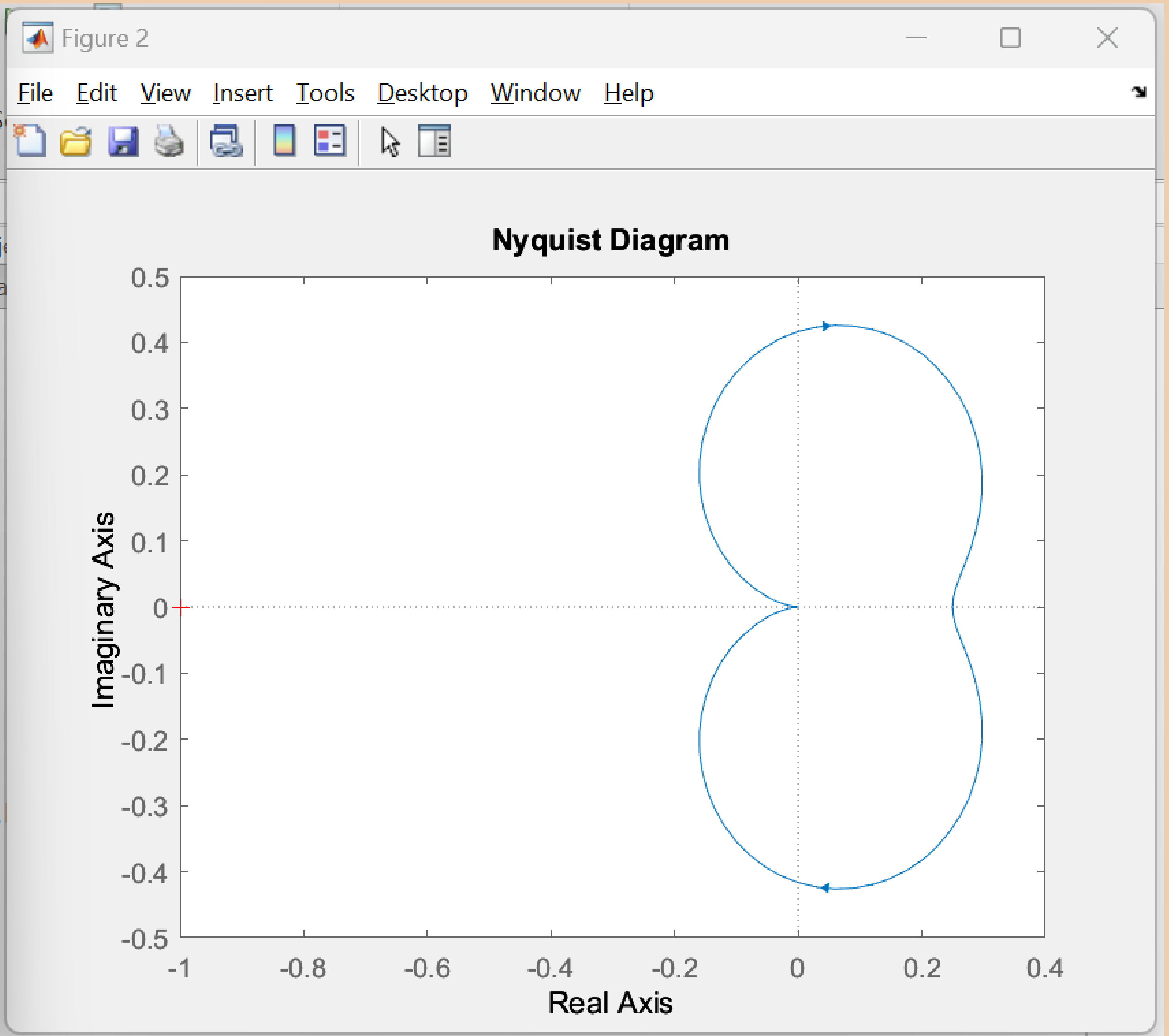


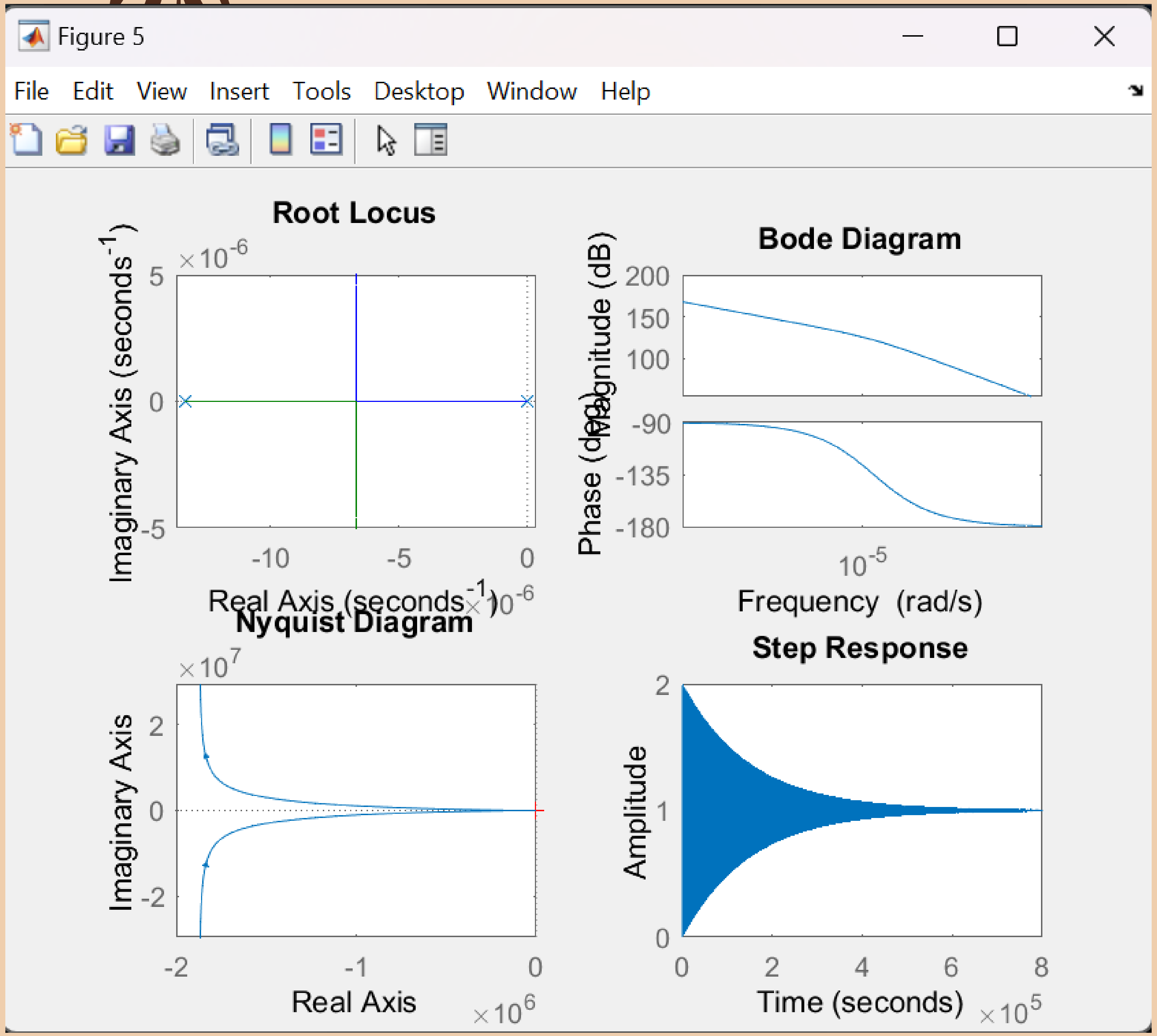
Figure 2
File Edit View Insert Tools Desktop Window Help
Nyquist Diagram
Imaginary Axis
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
Real Axis

OUTPUT (Q6a)

```
>> csp3q6a

Gm =

   Inf


Pm =

   Inf
```

-> Since our gain margin and phase margin are positive inf our system is very stable

OUTPUT (Q6b)



Gm =

Inf

Pm =

0.0418

Since our system is perfectly stable, we have made use of another trasfer function to depict lead and lag compensations

inference

If a system has an infinite gain margin, it indicates that its gain may be raised indefinitely without the system becoming unstable. In other words, the system is extremely resistant to changes in its gain. Similarly, if a system has an infinite phase margin, it signifies that the phase lag may be extended indefinitely without the system becoming unstable. This indicates that the system is highly robust to changes in its phase.

- In practical terms, an infinite gain margin and an infinite phase margin are highly desirable properties for a control system. They indicate that the system is highly stable and can handle large disturbances or uncertainties without becoming unstable
- Lead and Lag compensators are used to increase and decrease the phase margin respectively.

Applications:

-> to regulate temperature, flow, pressure, speed and other process variables.

->Industrial ovens

-> HVAC systems

->Refrigeration systems

->Chemical processing

->Water heating

Conclusion

We successfully controlled the temperature of our system using PID controllers and implemented all required questions as per project 3

Thank You