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Lab Assignment 5

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**Control Theory Lab 5 dated 06-09-2021.**

**Python Code:**

import numpy as np

import control

import matplotlib.pyplot as plt

# Case1

# Gs = 1/(s + 2) # Hs =1

b0 =1

a0 =2

a1 =1

den = np.array((a1,a0))

num = np.array((b0))

Gs = control.tf(num, den)

print("G(s) = ", Gs)

Hs = 1

# Root Locus

control.rlocus(Gs)

plt.title("Root locus for Case 1 (1/(s+2))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs)

plt.title("Pole zero map for Case 1 (1/(s+2))")

plt.figure()

t = np.arange(0,5,0.1)

T1, yout1 = control.step\_response(Gs, t, X0=0)

plt.plot(T1, yout1)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 1 (1/(s+2))")

plt.show()

G(s) =

1

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s + 2

Chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

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# Case2

# Gs = 1/(s+2)(s+4) # Hs =1

b00 =1

a00 =8

a01 =6

a02 =1

den1 = np.array((a02,a01,a00))

num1 = np.array((b00))

Gs1 = control.tf(num1, den1)

print("G(s) = ", Gs1)

# Root Locus

control.rlocus(Gs1)

plt.title("Root locus for Case 2 1/(s+2)(s+4))")

plt.figure()

# Pole Zero Map control.pzmap(Gs1)

plt.title("Pole zero map for Case 2 1/(s+2)(s+4))")

plt.figure()

t = np.arange(0,5,0.1)

T2, yout2 = control.step\_response(Gs1, t, X0=0)

plt.plot(T2, yout2)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 2 1/(s+2)(s+4))")

plt.show()

G(s) =

1

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s^2 + 6 s + 8

Chart, diagram

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Chart, box and whisker chart

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Chart, line chart

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# Case 3

# Gs = 1/(s+2)(s+4)(s+6)

# Hs = 1

b10 = 1

a10 =64

a11 =56

a12 =14

a13 = 1

den2 = np.array((a13,a12,a11,a10))

num2 = np.array((b10))

Gs2 = control.tf(num2,den2)

print("G(s) = ", Gs2)

# Root Locus

control.rlocus(Gs2)

plt.title("Root locus for Case 3 1/(s+2)(s+4)(s+6))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs2)

plt.title("Pole zero map for Case 3 1/(s+2)(s+4)(s+6))")

plt.figure()

t = np.arange(0,5,0.1)

T3, yout3 = control.step\_response(Gs2, t, X0=0)

plt.plot(T3, yout3)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 3 1/(s+2)(s+4)(s+6))")

plt.show()

G(s) =

1

------------------------

s^3 + 14 s^2 + 56 s + 64

Chart, diagram

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Chart, box and whisker chart

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Chart, line chart

Description automatically generated

# Case4

# Gs = 1/(s+2)(s+4)(s+0.1)

# Hs =1

b20 = 1

a20 =0.8

a21 =8.6

a22 =6.1

a23 = 1

den3 = np.array((a23,a22,a21,a20))

num3 = np.array((b20))

Gs3 = control.tf(num3,den3)

print("G(s) = ", Gs3)

# Root Locus

control.rlocus(Gs3)

plt.title("Root locus for Case 4 1/(s+2)(s+4)(s+0.1))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs3)

plt.title("Pole zero map for Case 4 1/(s+2)(s+4)(s+0.1))")

plt.figure()

t = np.arange(0,5,0.1)

T4, yout4 = control.step\_response(Gs3, t, X0=0)

plt.plot(T4, yout4)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 4 1/(s+2)(s+4)(s+0.1))")

plt.show()

G(s) =

1

---------------------------

s^3 + 6.1 s^2 + 8.6 s + 0.8

Chart, diagram, radar chart

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Chart, box and whisker chart

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Chart, line chart

Description automatically generated

**Effect of addition of zero to a transfer function**

# Case1

# Gs = 1/s(s + 2)(s+5)

# Hs =1

b0 =1

a0 =0

a1 = 10

a2 =7

a3 =1

den = np.array((a3,a2,a1,a0))

num = np.array((b0))

Gs = control.tf(num, den)

print("G(s) = ", Gs)

Hs = 1

# Root Locus

control.rlocus(Gs)

plt.title("Root locus for Case 1 1/s(s + 2)(s+5))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs)

plt.title("Pole zero map for Case 1 1/s(s + 2)(s+5))")

plt.figure()

t = np.arange(0,5,0.1)

T1, yout1 = control.step\_response(Gs, t, X0=0)

plt.plot(T1, yout1)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 1 1/s(s + 2)(s+5))")

plt.show()

G(s) =

1

------------------

s^3 + 7 s^2 + 10 s

Chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

Description automatically generated

# Case2

# Gs = (s+3)/s(s + 2)(s+5)

# Hs =1

b00 =3

b01 =1

a00 =0

a01 = 10

a02 =7

a03 =1

den1 = np.array((a03,a02,a01,a00))

num1 = np.array((b01,b00))

Gs1 = control.tf(num1, den1)

print("G(s) = ", Gs1)

Hs = 1

# Root Locus

control.rlocus(Gs1)

plt.title("Root locus for Case 2 (s+3)/s(s + 2)(s+5))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs1)

plt.title("Pole zero map for Case 2 (s+3)/s(s + 2)(s+5))")

plt.figure()

t = np.arange(0,5,0.1)

T2, yout2 = control.step\_response(Gs1, t, X0=0)

plt.plot(T2, yout2)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 2 (s+3)/s(s + 2)(s+5))")

plt.show()

G(s) =

s + 3

------------------

s^3 + 7 s^2 + 10 s

Chart, line chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

Description automatically generated

# Case3

# Gs = (s+7)/s(s + 2)(s+5)

# Hs =1

b10 =7

b11 =1

a10 =0

a11 = 10

a12 =7

a13 =1

den2 = np.array((a13,a12,a11,a10))

num2 = np.array((b11,b10))

Gs2 = control.tf(num2, den2)

print("G(s) = ", Gs2)

Hs = 1

# Root Locus

control.rlocus(Gs2)

plt.title("Root locus for Case 3 (s+7)/s(s + 2)(s+5))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs2)

plt.title("Pole zero map for Case 3 (s+7)/s(s + 2)(s+5))")

plt.figure()

t = np.arange(0,5,0.1)

T3, yout3 = control.step\_response(Gs2, t, X0=0)

plt.plot(T3, yout3)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 3 (s+7)/s(s + 2)(s+5))")

plt.show()

G(s) =

s + 7

------------------

s^3 + 7 s^2 + 10 s

Chart, line chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

Description automatically generated

# Case4

# Gs = (s+1)/s(s + 2)(s+5)

# Hs =1

b20 =1

b21 =1

a20 =0

a21 = 10

a22 =7

a23 =1

den3 = np.array((a23,a22,a21,a20))

num3 = np.array((b21,b20))

Gs3 = control.tf(num3, den3)

print("G(s) = ", Gs3)

Hs = 1

# Root Locus

control.rlocus(Gs3)

plt.title("Root locus for Case 4 (s+1)/s(s + 2)(s+5))")

plt.figure()

# Pole Zero Map

control.pzmap(Gs3)

plt.title("Pole zero map for Case 4 (s+1)/s(s + 2)(s+5))")

plt.figure()

t = np.arange(0,5,0.1)

T4, yout4 = control.step\_response(Gs3, t, X0=0)

plt.plot(T4, yout4)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response for Case 4 (s+1)/s(s + 2)(s+5))")

plt.show()

G(s) =

s + 1

------------------

s^3 + 7 s^2 + 10 s

Chart, line chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

Description automatically generated

**Effect of addition of zero to a standard second order transfer function**

# Case 1 Zero at s=-0.5

B11 = 1

B10 = 0.5

num8 = np.array((B11,B10))

Hs1 = control.tf(num8,den8)

print("H(s) = ", Hs1)

# Root Locus

control.rlocus(Hs1)

plt.title("Root Locus Case 1 zero at s=-0.5")

plt.figure()

# Pole Zero Map

control.pzmap(Hs1)

plt.title("Pole Zero Plot Case 1 zero at s=-0.5")

plt.figure()

t = np.arange(0,15,0.1)

T8, yout8 = control.step\_response(Hs1, t, X0=0)

plt.plot(T8, yout8)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response Case 1 zero at s=-0.5")

plt.show()

plt.figure()

H(s) =

s + 0.5

-----------

s^2 + s + 1

Chart, diagram

Description automatically generated

Chart

Description automatically generated

Chart, line chart

Description automatically generated

# Case 2 zero at s=-1

B21 =1

B20 =1

num9 = np.array((B21,B20))

Hs2 = control.tf(num9,den8)

print("H(s) = ", Hs2)

# Root Locus

control.rlocus(Hs2)

plt.title("Root Locus Case 2 zero at s=-1")

plt.figure()

# Pole Zero Map

control.pzmap(Hs2)

plt.title("Pole Zero Plot Case 2 zero at s=-1")

plt.figure()

t = np.arange(0,15,0.1)

T9, yout9 = control.step\_response(Hs2, t, X0=0)

plt.plot(T9, yout9)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response Case 2 zero at s=-1")

plt.show()

plt.figure()

H(s) =

s + 1

-----------

s^2 + s + 1

Chart

Description automatically generated

Chart

Description automatically generated

Chart, line chart

Description automatically generated

# Case 3 zero at s=-8

B31 =1

B30 =8

num10 = np.array((B31,B30))

Hs3 = control.tf(num10,den8)

print("H(s) = ", Hs3)

# Root Locus

control.rlocus(Hs3)

plt.title("Root Locus Case 3 zero at s=-8")

plt.figure()

# Pole Zero Map control.pzmap(Hs3)

plt.title("Pole Zero Plot Case 3 zero at s=-8")

plt.figure()

t = np.arange(0,15,0.1)

T10, yout10 = control.step\_response(Hs3, t, X0=0)

plt.plot(T10, yout10)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response Case 3 zero at s=-8")

plt.show()

plt.figure()

# Case 3 zero at s=-8

B31 =1

B30 =8

num10 = np.array((B31,B30))

Hs3 = control.tf(num10,den8)

print("H(s) = ", Hs3)

# Root Locus

control.rlocus(Hs3)

plt.title("Root Locus Case 3 zero at s=-8")

plt.figure()

# Pole Zero Map

control.pzmap(Hs3)

plt.title("Pole Zero Plot Case 3 zero at s=-8")

plt.figure()

t = np.arange(0,15,0.1)

T10, yout10 = control.step\_response(Hs3, t, X0=0)

plt.plot(T10, yout10)

plt.xlabel("Time in sec")

plt.ylabel("Y(t)")

plt.grid()

plt.title("Step Response Case 3 zero at s=-8")

plt.show()

plt.figure()

H(s) =

s + 8

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s^2 + s + 1

Chart

Description automatically generated

Chart, box and whisker chart

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Chart, line chart

Description automatically generated

**Learning outcomes:**

1. Using Control Library in Python
2. Plotting Pole zero maps using control
3. The effect of adding a pole or a zero to a transfer function

**Conclusion:**

* Addition of poles to the transfer function of the system moves the root locus towards the right side of the imaginary axis.
* Addition of zeros to the transfer function of the system moves the root locus towards the left side of the imaginary axis
* Therefore, the system becomes unstable at the right of the imaginary axis and the system is stable when on the left side of the imaginary axis
* While adding zeros to the second-order transfer function the root locus shifts to the left side of the imaginary axis